#40460564
ID88049784

OZARK UNDERGROUND LABORATORY
Protem, Missouri 65733 • (417) 785-4289

BLM LIBRARY
88049784
GB
606
.W8
T747
1979

Cave Assessment, Monitoring, and Management Recommendations for La Caverna de los Tres Charros, Bureau of Land Management, Worland District, Wyoming.

October, 1979

Tom and Cathy Aley
Ozark Underground Laboratory

BLM LIBRARY
SC-653, BLDG. 50
DENVER FEDERAL CENTER
P. O. BOX 25047
DENVER, CO 80225-0047

This report was prepared under contract WY910-CT9-008 for the Bureau of Land Management, U.S. Department of Interior.

EXECUTIVE SUMMARY

La Caverna de los Tres Charros is one of the largest caves in Wyoming. The cave displays substantial vertical development; the deepest point presently known in the cave is about 300 feet lower than the entrance. The cave contains interesting and significant hydrologic features, including waterfalls, cascades, lakes, and stream passages. The cave also contains an interesting fauna which includes about ten species of invertebrates.

Management conclusions and recommendations for Tres Charros are briefly summarized in the following sections. Detailed discussions of the rationale and justifications for these recommendations are found in the text of this report.

Commonly recognized cave hazards

1. People visiting any BLM cave should be cautioned about slippery walking surfaces, loose and shifting rocks, the possibility of becoming lost, the need for carrying adequate lights, and the risk of falling off boulders or down pits.
2. Hazards associated with loose and shifting rocks in Tres Charros do not represent an unusually significant hazard.
3. The hazard of becoming lost is not unusually significant in Tres Charros.
4. Visitors to Tres Charros should be advised that the cave is of such size and complexity that good lights are needed. People planning to explore the cave should carry at least two sources of acceptable light.
5. Visitors to Tres Charros should be cautioned about the four areas where ropework is required or recommended, and should be advised of the equipment needed.
6. The danger of being trapped or drowned by underground flooding is the most significant safety hazard at Tres Charros. People could either drown or die of hypothermia. The flooding and entrapment hazards can be reduced by a management strategy which includes the following components:

A) Establishment of a check-out procedure for all visitors to insure that they are aware of the hazards and are adequately equipped.

B) Establishment of a procedure for promptly notifying BLM once parties have left the cave.

C) Installation of a sign at the cave to inform visitors that a permit was required for entry. The sign would also warn of flooding and hypothermia hazards, and would thus insure that even trespassers were aware of these hazards.

D) Involvement of visitors in a program to make them more aware of the flooding hazards. This program would involve developing a correlation between streamflow volumes on the surface and flooding conditions in the cave.

E) Maintenance of the existing survival cache in the cave. In addition, each visitor would be required to carry with him a dry set of warm clothes to withstand flood entrapment.

F) Development of a rescue plan for people trapped by flood waters. A hydrologic strategy for lowering floodwaters in the cave to permit search and rescue is discussed in detail in this report, but represents only a portion of the recommended rescue plan.

Histoplasmosis

1. Histoplasmosis should not be considered a health or safety hazard in this cave, and no warning to visitors is deemed necessary.
2. The results of Histoplasma capsulatum culturing is not yet known. When the analysis is completed, an addendum to this report will be prepared. It is highly unlikely that the fungus will be found in any of these samples.

Alpha radiation

1. Alpha radiation should not be considered a significant health hazard at this cave.
2. Based upon the low alpha radiation concentrations measured in Tres Charros and the short duration of visitation, it is not necessary for BLM to caution visitors to this cave about cave radiation.
3. Additional alpha radiation monitoring in this cave is not recommended.

Feasibility of gating the cave

1. A gate is not feasible for Tres Charros. Approaches other than gates will have to be used to control access to this cave. Access control is needed to insure that visitors are adequately informed of the hazards present in the cave, and to insure that rescue efforts could be started promptly in the event of accidents or visitor entrapment by floods.
2. Since a gate is not feasible, we recommend the following approaches for controlling access:

A) Local cavers and caving clubs should be informed that permits are required for each visit to this cave, and that these permits are required because of safety considerations.

B) Visitors to other BLM caves should be informed in writing on their permits that permits are also required for visits to La Caverna de los Tres Charros. This will insure that most active cavers are aware of the permit requirement.

C) A sign should be placed at the entrance to Tres Charros informing people that permits are required for cave entry. The sign should also inform potential visitors of the hazards present in the cave.

General cave management

1. La Caverna de los Tres Charros is a large cave with state significance. It is an important natural resource.
2. The cave is very appealing for cave explorers.
3. The cave contains a fauna which, for such a northern climate, is both large and diverse. The fauna may be of scientific interest. The cave fauna is not highly susceptible to damage from human use of the cave.

Additional investigations

1. Groundwater tracing should be conducted to determine if waters from Taylor Camp Creek contribute to the flooding of Tres Charros.
2. Staff gages should be installed on both Dry Medicine Lodge Creek and on Taylor Camp Creek.
3. Areas of the cave where people could escape floodwaters should be depicted on maps.
4. Recommendations should be developed for additional survival cache locations in the cave, and for the contents of these caches.
5. A rescue plan should be developed for the cave.

TABLE OF CONTENTS

EXECUTIVE SUMMARY....1
LIST OF FIGURES....5
LIST OF TABLES....7
LIST OF APPENDICES....8
LOCATION OF CAVE ENTRANCE....9
DESCRIPTION OF CAVE FEATURES AND VALUES....12
Cave Passages....12
Waterfall and cascade passages....12
Present and abandoned stream passages....14
Large collapse chambers....23
High fissure passages....23
The Inclined Room 27
Cave Fauna....27
Hydrology of the cave....30
HEALTH AND SAFETY....40
Commonly recognized cave hazards....40
Loose and shifting rocks....40
Becoming lost....40
Failure of all lights....40
Falling down pits or climbs....41
Being trapped or drowned by underground floodwaters....43
Preliminary rescue strategy for people trapped in the cave by floodwaters....45
Management recommendations on commonly recognized cave hazards....49
Commonly unrecognized cave hazards....50
Histoplasmosis and other lung diseases....50
Management recommendations on histoplasmosis....51
Naturally occurring alpha radiation....51
Management recommendations on alpha radiation....56
FEASIBILITY OF GATING THE CAVE....57
GENERAL CAVE MANAGEMENT AND RECOMMENDATIONS....58
RECOMMENDATIONS FOR ADDITIONAL INVESTIGATIONS....60
REFERENCES....61
APPENDICES....62

LIST OF FIGURES

1. The location of the entrance to La Caverna de los Tres Charros (photo). 10

2. The entrance to La Caverna de los Tres Charros (photo). 11

3. La Caverna de los Tres Charros. Map adapted from Hill et al. (1976) and sketch map accompanying Monsson (1974). 13

4. Location of major underground waterfall areas in La Caverna de los Tres Charros (map). 15

5. The lower waterfall on the Main Stream Passage. This waterfall is approximately 20 ft. high. View from the Cataract Room looking west (photo). 16

6. Waterfall on the Second Stream. This view is from the Cataract Room looking east (photo). 17

7. Waterfall near the bottom of the Punch Bowl Passage (photo). . . . 18

8. Major present and abandoned stream passages in the cave (map). . . 19

9. A typical stream passage in La Caverna de los Tres Charros showing pools of water in the Hayford Canyon portion of the cave (photo). .20

10. A typical stream passage in La Caverna de los Tres Charros. Bedding planes are steeply inclined in much of the cave. Note the pieces of insoluble chert protruding from the soluble dolomite; this indicates that solution is an important process in passage enlargement (photo). 21

11. A typical stream passage in La Caverna de los Tres Charros (photo).22

12. Solutional erratics on the passage floor in a typical stream passage (photo). 24

13. The location of the Big Room, a large collapse chamber (map). . . 25

14. The location of high fissure passages in La Caverna de los Tres Charros (map). 26

15. The location of the Inclined Room in La Caverna de los Tres Charros (map). 28

16. Surface stream in Dry Medicine Lodge Creek. The man is standing near the point where the stream disappears underground. The entrance to Dry Medicine Lodge Creek Cave is in the background (photo).31

17. A swallowhole on Dry Medicine Lodge Creek near the entrance to Dry Medicine Lodge Creek Cave (photo). 32

18. Entrance to Dry Medicine Lodge Creek Cave (photo). 33

19. Location of dye recovery points (Monsson, 1974) (map). 34

20. Location of climbs and pits where technical ropework is required or recommended (map). 42

21. Location of sample sites for Histoplasma capsulatum (map). . . . 52

22. Alpha radiation monitoring stations (map). 55

LIST OF TABLES

1. Travel times and distances for dye injected in Dry Medicine Lodge Creek near the entrance to Dry Medicine Lodge Creek Cave. Data from Monsson (1974). 35

2. Estimates on the likely effects of various streamflow rates on cave explorers in La Caverna de los Tres Charros. 38

3. Location and related data on soil and fecal samples collected in La Caverna de los Tres Charros for Histoplasma capsulatum analysis. 53

4. Results of September 8, 1979 alpha radiation and air temperature monitoring in La Caverna de los Tres Charros. 54

LIST OF APPENDICES

A. Articles on cave explorers trapped underground by floods. 62

B. Detailed discussion of histoplasmosis from the Spirit Mountain Caverns report. 65

C. Discussion of cave radiation. 70

Attachment 1: National Caves Association precautionary cave radiation health standards for natural caves developed for visitation by the general public. . . 75

D. Articles on the hazards of hypothermia. 76

LOCATION OF THE CAVE ENTRANCE

La Caverna de los Tres Charros has one entrance (Figures 1 and 2). The entrance is located behind a 20-foot high slab of rock which has hinged away from the cliff face. The entrance is located about five feet above the floor of the main channel of Dry Medicine Lodge Creek. Upon entering the cave, one quickly descends below the elevation of the surface stream channel.

The entrance to Tres Charros is on the northwest side of the main branch of Dry Medicine Lodge Creek at the extreme western edge of Section 4, T51N, R88W. The area is shown on the Spanish Point 7½ minute topographic map of 1960. The entrance is in the NW¼ SW¼ of Section 4, and is located at an elevation of about 7,920 feet.

The description of the legal location of the cave has sometimes been confused in the past because sections 4 and 5 are of unequal size, and there are two lines about a quarter mile apart on the topographic map which seem to divide these two sections. Our description is correct. To avoid future confusion, the entrance to La Caverna de los Tres Charros is approximately 500 feet upstream of the major stream junction shown in the eastern portion of section 5.

The best route to the cave is via a jeep road from Taylor Cow Camp (Section 9, T51N, R88W). Since the topographic map was printed, the main gravel road shown in section 4 has been abandoned; the road has been relocated about 3/4 mile east. This relocation can cause confusion when one tries to find the cave.

Figure 1. The location of the entrance to La Caverna de los Tres Charros. (Note: photo printed backwards).

Figure 2. The entrance to La Caverna de los Tres Charros.

DESCRIPTION OF CAVE FEATURES AND VALUES

La Caverna de los Tres Charros is a large alpine cave system developed in the Big Horn dolomite of Ordovician age (Hill et al., 1976; Monsson, 1974). Hill et al. (1976) reported that 2,277 feet of passages have been mapped in the cave. Monsson (1974) reported that over 3,640 feet of passages have been mapped. Based upon our field work, the total length of presently known passages in this cave is probably close to a mile. A number of passages are unmapped. Based upon the amount of passage alone, Tres Charros is one of the major caves of Wyoming.

Figure 3 is a map we developed from the mapping and sketch notations which accompanied the Monsson (1974) report. This is the most comprehensive map presently accessible to us. The accuracy of the mapping is unknown, but the map is generally adequate for cave management purposes.

La Caverna de los Tres Charros displays substantial vertical development. The deepest point presently known in the cave is about 300 feet lower than the entrance. There is no cave development presently known above the elevation of the cave entrance, but surface evidence indicates that such passages may well exist. There are small openings between talus blocks on the hillside above the entrance to Tres Charros, and it is possible that one could enter solutional passages with enough exploration around the talus blocks.

Cave passages

To simplify the discussion of cave features and values, five categories of passages found in the cave have been identified. The use of these categories will increase the value of this report for BLM land management purposes. The five classes are:

1. Waterfall and cascade passages
2. Present and abandoned stream passages
3. Large collapse chambers
4. High fissure passages
5. The Inclined Room

Waterfall and cascade passages. Waterfall and cascade passages are among the most impressive features in La Caverna de los Tres Charros. Water rushing and cascading through the cave passages is noisy and impressive, but also a bit frightening. The cave can obviously flood with great rapidity. Because of this problem, and the importance of water in this cave system, the hydrology of the cave and the surrounding area will be discussed in a separate portion of this report.

During field work in September, 1979, four major waterfall areas in the cave were found. These represented four tributary stream systems. Based upon a map of the cave by Hill et al. (1976) these waterfall areas are known by the following names:

1. Bat Veil Falls area (main stream)
2. Cataract Room (second stream)
3. Punch Bowl Passage (third stream)
4. Waterfall Room

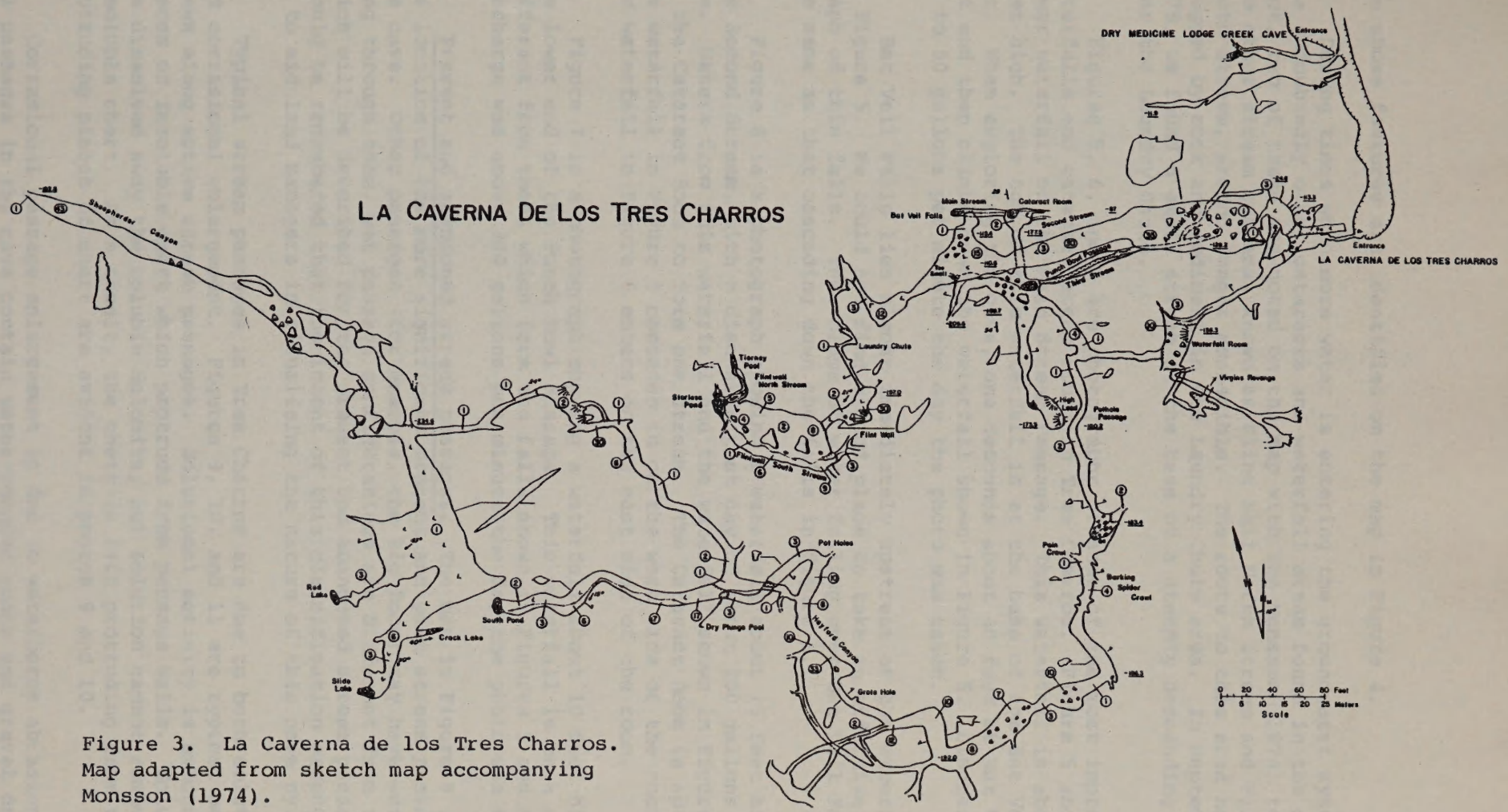
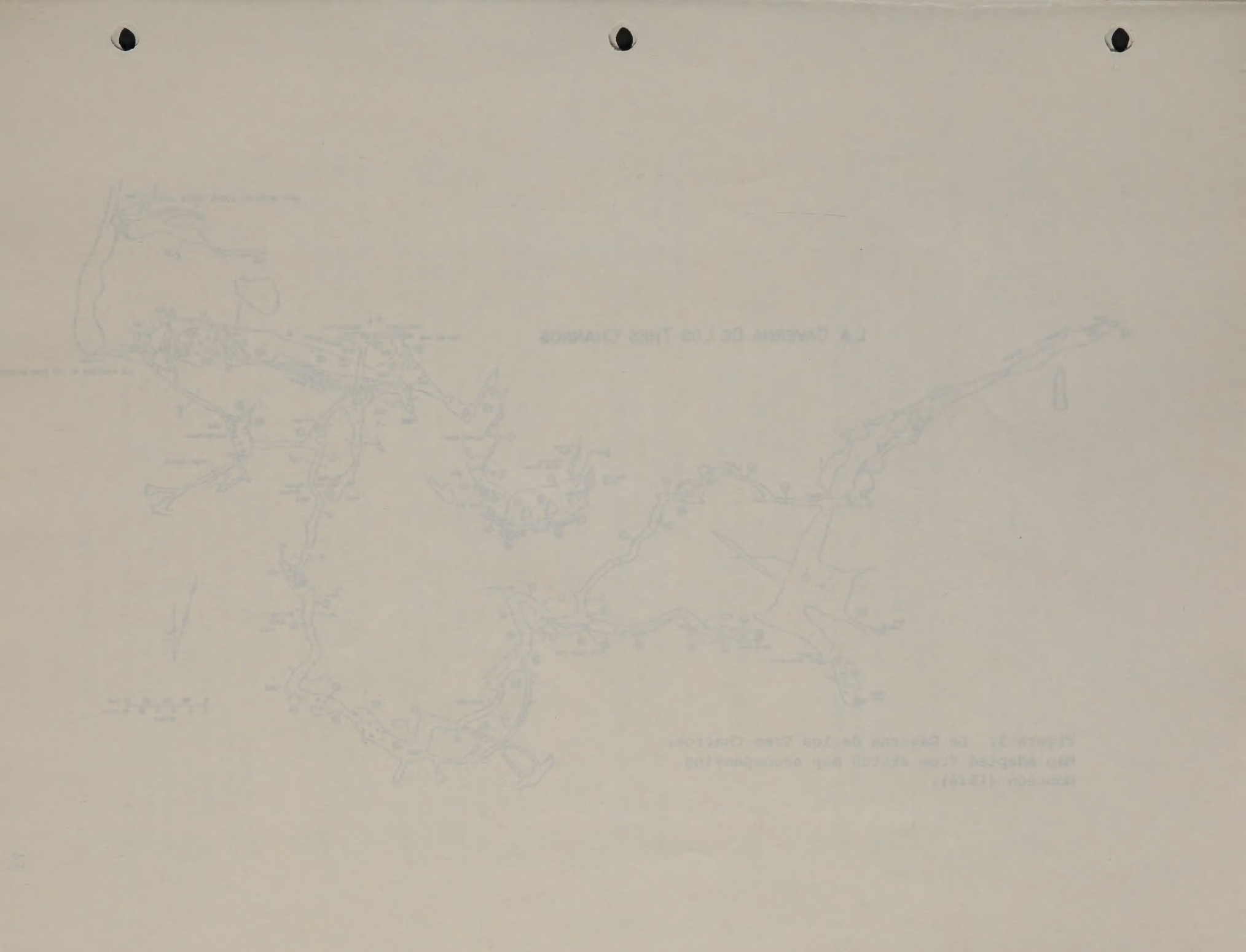


Figure 3. La Caverna de los Tres Charros. Map adapted from sketch map accompanying Monsson (1974).



The above features are identified on the map in Figure 4.

During times when more water is entering the groundwater system, there are undoubtedly other cataracts and waterfall areas found in the cave. In fact, two of these are noted on the map with the Monsson (1974) report. Two other stream systems, known as Flint Wall North Stream and Flint Wall South Stream, are no longer accessible. The route to this area has been plugged by rock and sediment in the Laundry Chute area. In September, 1979, we found a small stream at the base of a steeply descending passage near the Laundry Chute.

Figures 5, 6, and 7 are photographs of some of the most impressive waterfalls and cataract areas found in Tres Charros. Figure 5 shows the lower waterfall on the Main Stream Passage. This waterfall is about 20 feet high. The top of this waterfall is at the base of the Bat Veil Falls Pit. When exploring the cave, one descends about 40 feet at Bat Veil Falls Pit and then climbs down the waterfall shown in Figure 5. Discharge was 30 to 50 gallons per minute the day the photo was taken.

Bat Veil Falls lies almost immediately upstream of the waterfall shown in Figure 5. We could not find a good place to take an effective photograph of this falls. The volume of water falling over Bat Veil Falls is the same as that cascading down the falls in Figure 5.

Figure 6 is a photograph showing a waterfall about 15 feet high on the Second Stream, with a discharge that day of about 100 gallons per minute. Waters from this waterfall and the waterfall shown in Figure 5 join in the Cataract Room to form one stream. The Cataract Room is aptly named; the waterfall in Figure 5 cascades in on the west side of the room, and the waterfall in Figure 6 enters on the east side of the room.

Figure 7 is a photograph showing a waterfall about 10 feet high near the lower end of the Punch Bowl Passage. This waterfall is on a stream different from those which form the falls shown in Figures 5 and 6. The discharge was about 300 gallons per minute the day the photo was taken.

Present and abandoned stream passages. The map in Figure 8 indicates the location of the more significant present and past stream passages in the cave. Other passages (for example, the Big Room) may have water running through them, yet passage configurations are different from those which will be described for the present and abandoned stream passages. It should be remembered that the intent of this classification arrangement is to aid land managers in visualizing the nature of this cave system.

Typical stream passages in Tres Charros are due to both solutional and corrasional enlargement. Figures 9, 10, and 11 are typical passage views along active stream passages. Solutional activity is evidenced by pieces of insoluble chert which protrude from passage walls. Solution has dissolved away the soluble dolomite, but solution cannot remove the insoluble chert. As a result, the chert is left protruding from the walls. Protruding pieces of chert are evident in photos 9 and 10.

Corrasional passage enlargement is due to waterborne abrasion. Typical passages in the cave contain water-rounded rocks and gravel derived

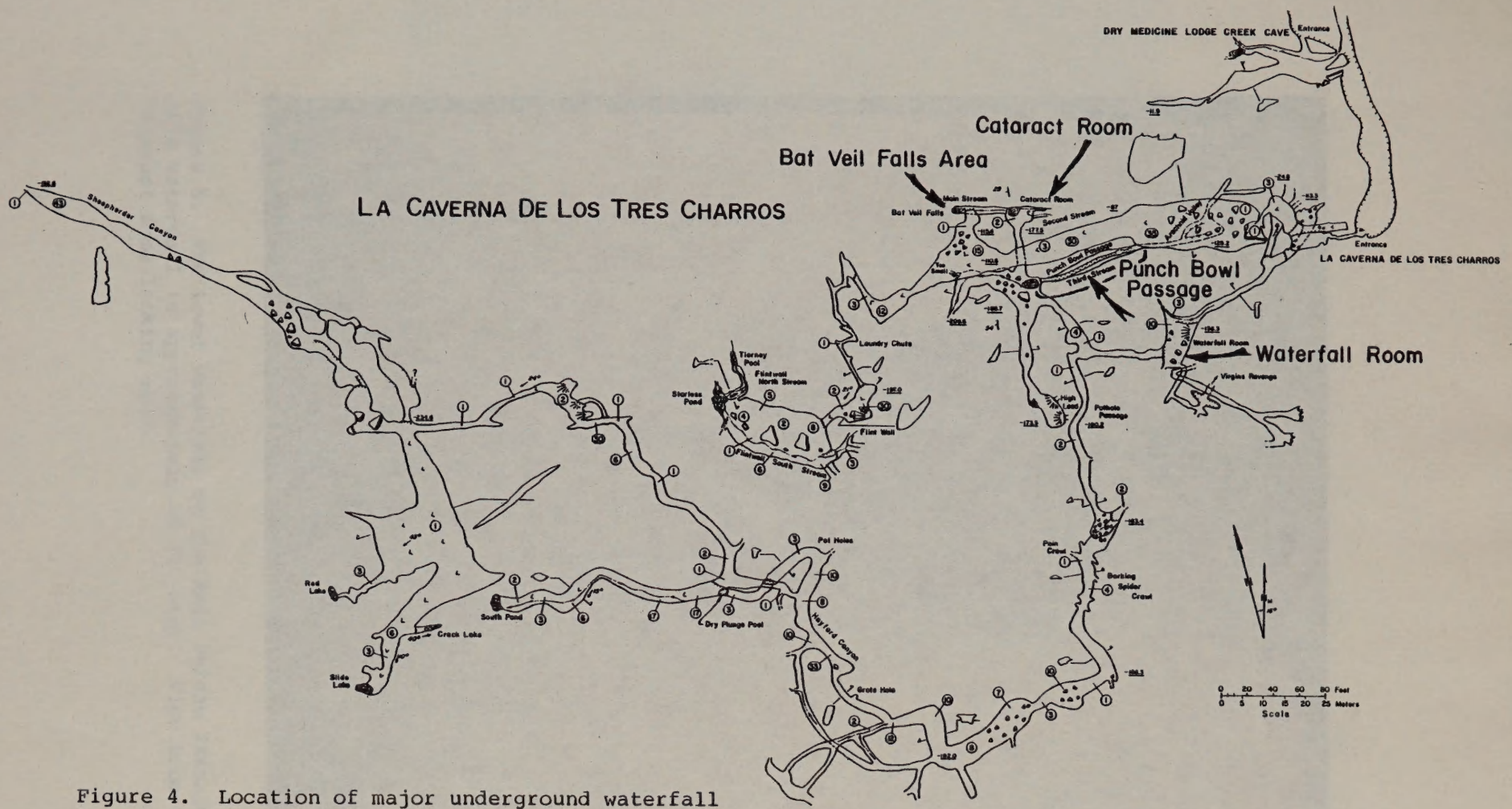


Figure 4. Location of major underground waterfall areas in La Caverna de los Tres Charros.

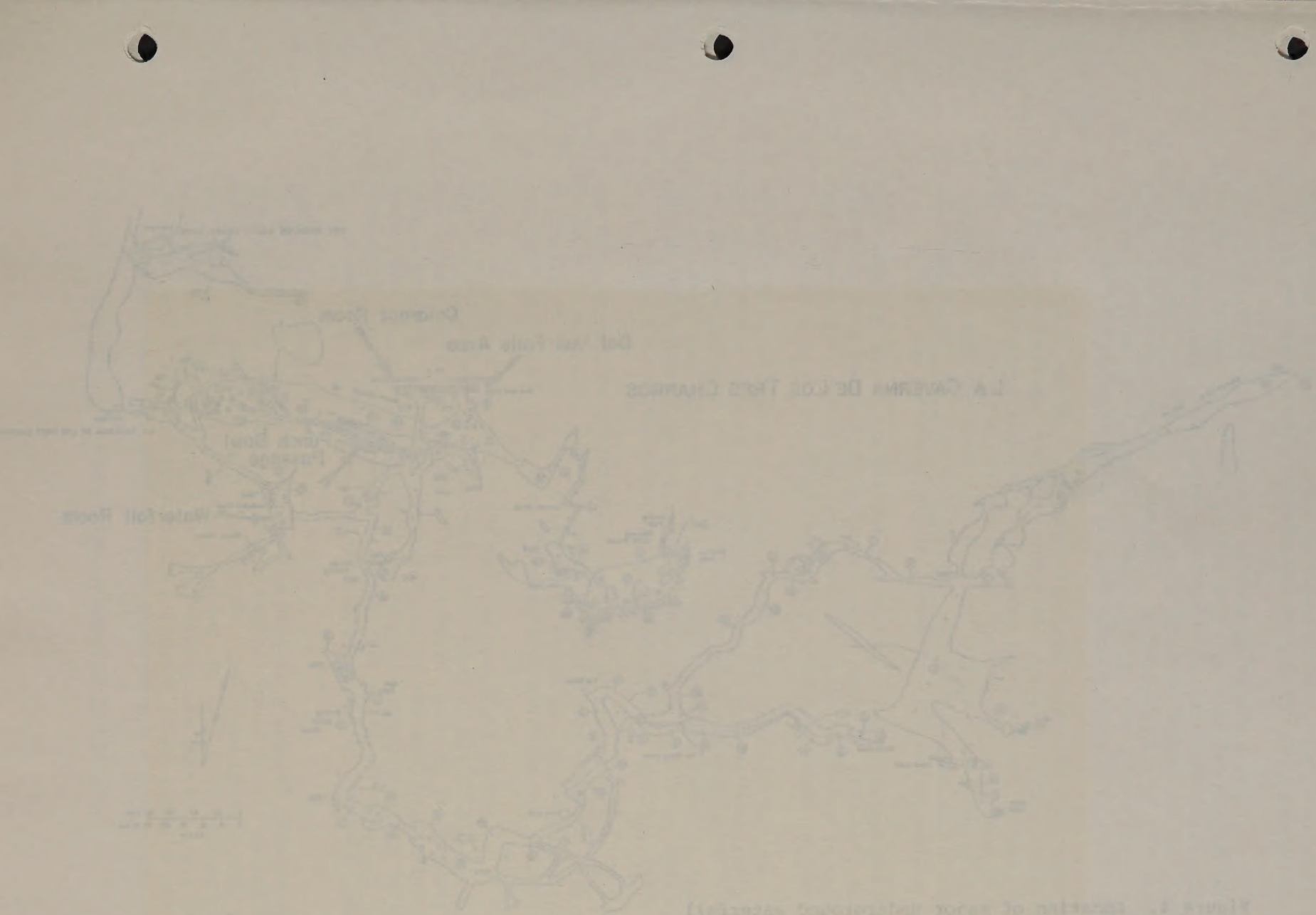


Figure 5. The lower waterfall on the Main Stream Passage. This waterfall is approximately 20 ft. high. View from the Cataract Room looking west.

Figure 6. Waterfall on the Second Stream. This view is from the Cataract Room looking east.

Figure 7. Waterfall near the bottom of the Punch Bowl Passage.

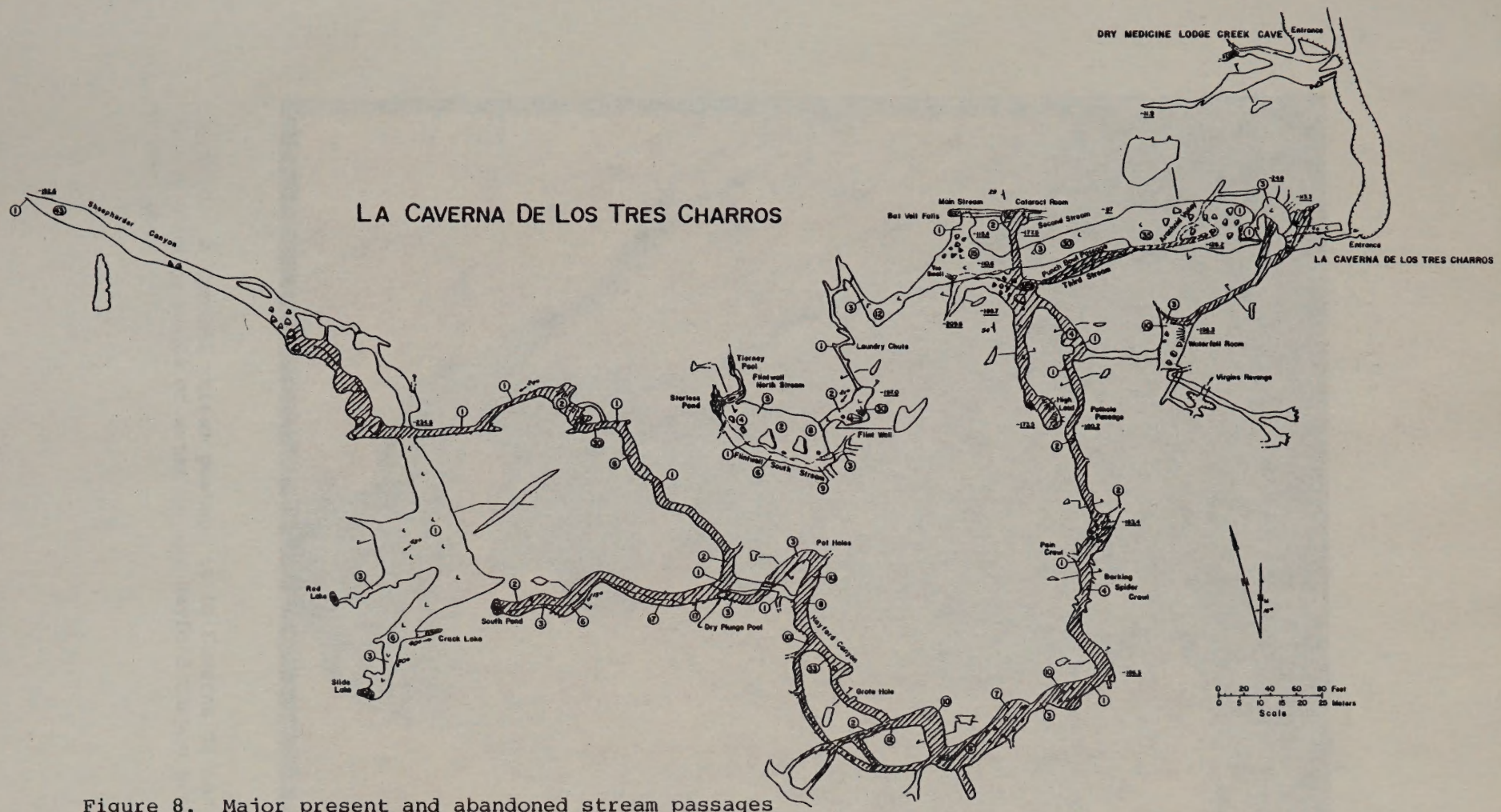


Figure 8. Major present and abandoned stream passages in the cave. See text for explanation.

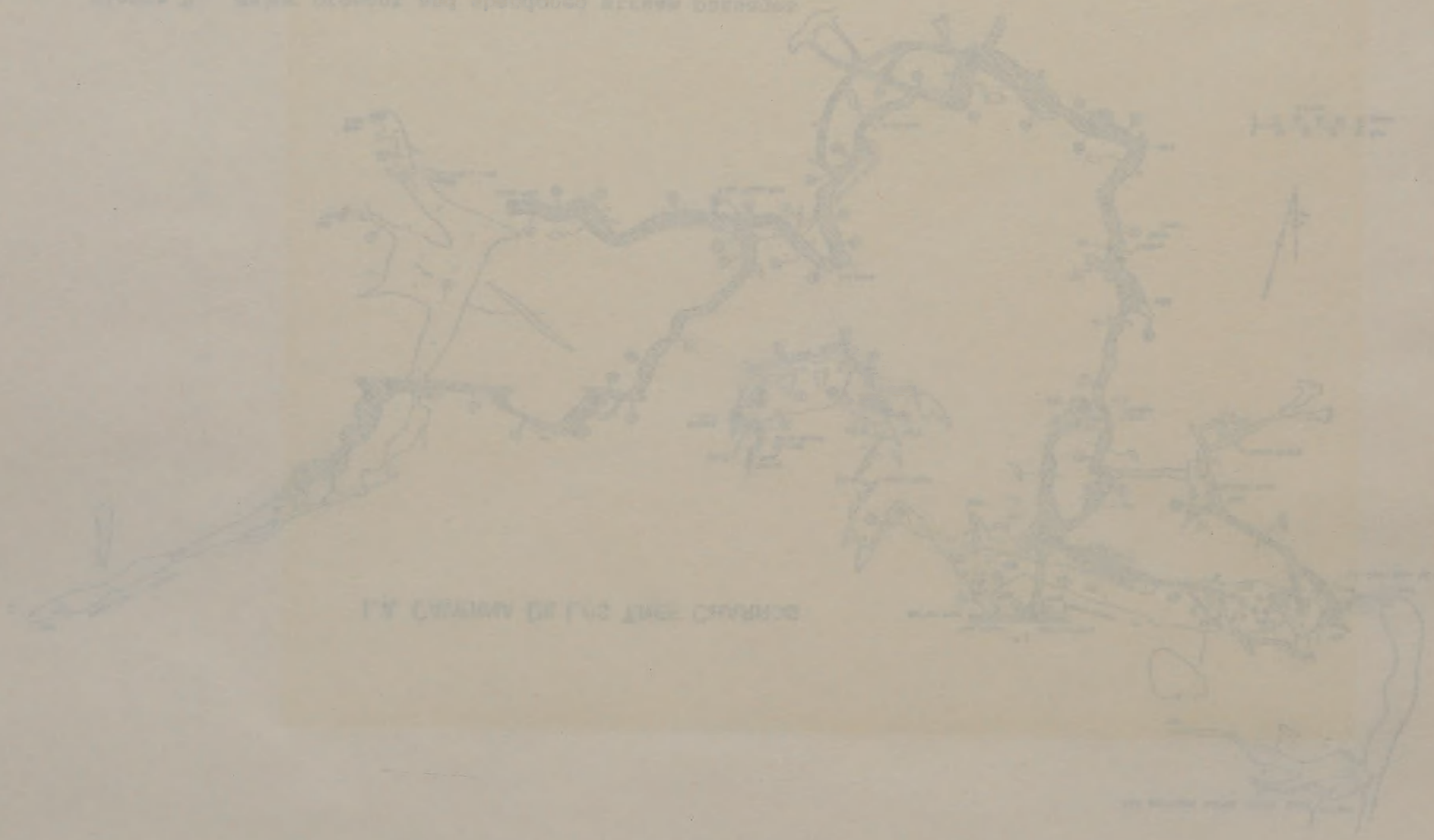


Figure 9. A typical stream passage in La Caverna de los Tres Charros showing pools of water in the Hayford Canyon portion of the cave.

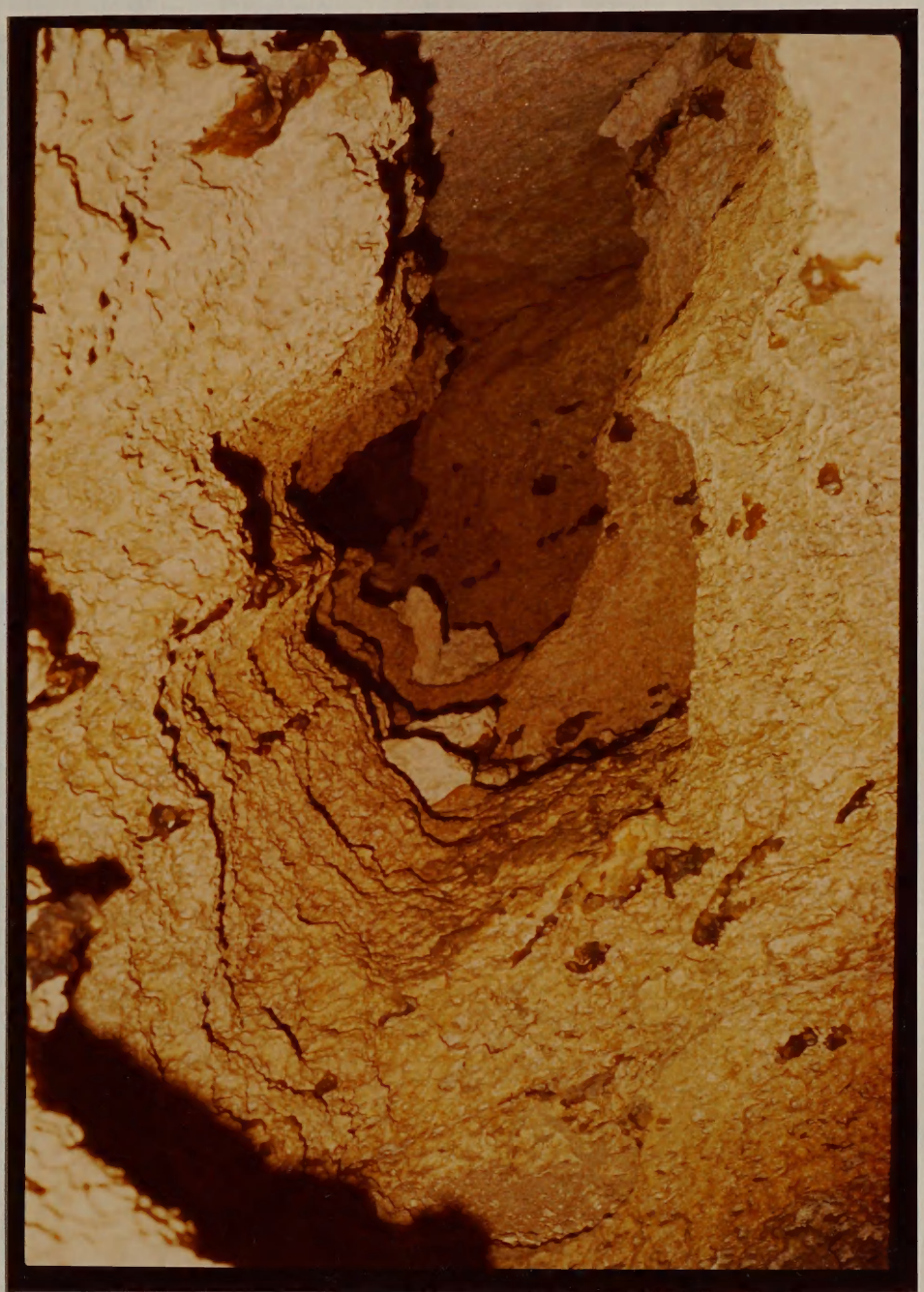


Figure 10. A typical stream passage in La Caverna de los Tres Charros. Bedding planes are steeply inclined in much of the cave. Note the pieces of insoluble chert protruding from the soluble dolomite; this indicates that solution is an important process in passage enlargement.

Figure 11. A typical stream passage in La Caverna de los Tres Charros.

from outside of the cave. Even deep in the cave one can find rounded rocks several inches in diameter.

Many of the stream passages are very irregular because of solutional action by stream waters. Solutional erratics on the passage floor are shown in Figure 12.

In some places, stream passages are flooded for substantial periods during periods of heavy runoff. This inundation deposits fine textured sediments on the cave floor. These sediments are particularly common in the following types of locations:

1. Abandoned stream passages. Sediments are deposited during flood periods, but are not subsequently flushed out by flowing water.
2. Active stream passages with low gradients, or points where the elevation of the floor of a stream passage increases downstream. Cavers typically call these sumps or siphons.
3. Areas within about 80 feet of the low water elevation of ponds within the cave. During flood periods, these passages are completely under water, and fine textured sediments settle to the passage floors.

The stream passages in Tres Charros are esthetically appealing passages to explore. They are interesting, and in most places can be traversed fairly easily (although one has to climb around pools and crawl through some low places). The stream passages represent the largest single category of passages found in the cave, and account for much of the complexity and recreational value possessed by the cave.

Large collapse chambers. There is only one large collapse chamber in the cave; this is the Big Room. Some smaller collapse chambers exist, and in some areas collapse has occurred along stream passages, but these features do not warrant particular attention. Figure 13 shows the location of the Big Room.

The Big Room, which is the first major chamber encountered in the cave, is about 240 feet long. It varies in width from 15 to 30 feet, and has ceiling heights ranging from 15 to 35 feet. From the eastern to the western end of the Big Room the passage drops about 100 feet in elevation.

The Big Room is a large joint controlled passage where substantial collapse has occurred. The floor is covered with large breakdown blocks, plus gravel, boulders, and sticks flushed into the cave by flood water torrents. Travel in the room requires climbing and scrambling over breakdown blocks.

Invertebrate fauna found in the cave is particularly abundant on sticks and other organic debris in the Big Room. A section of this report entitled "Cave fauna" discusses this in detail.

High fissure passages. The map in Figure 14 shows the location of high fissure passages in Tres Charros. The tallest of these is the Virgin's Promise Pit, an eliptical fissure passage about 100 feet high. By

Figure 12. Solutional erratics on the passage floor in a typical stream passage.

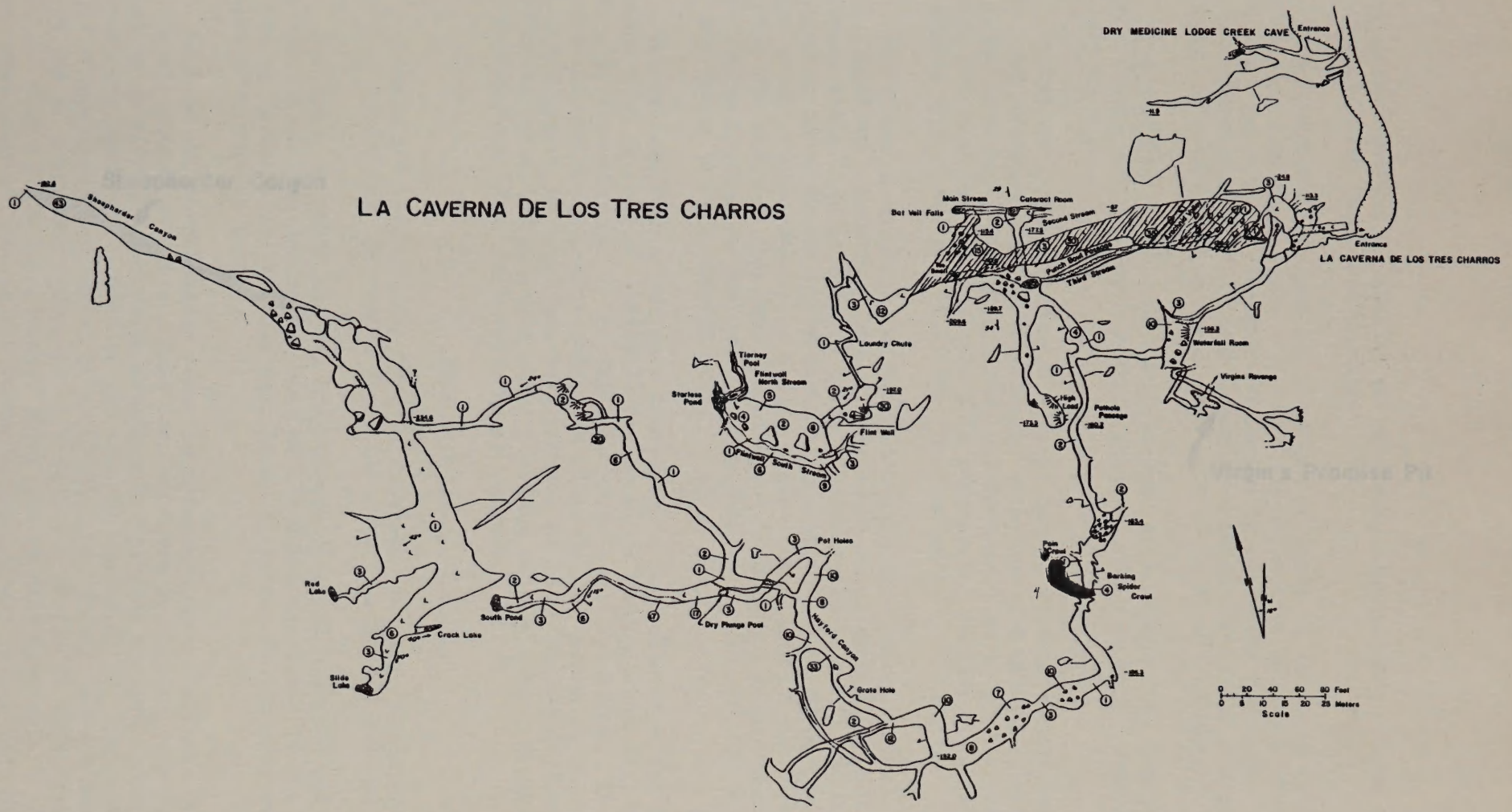


Figure 13. The location of the Big Room, a large collapse chamber.

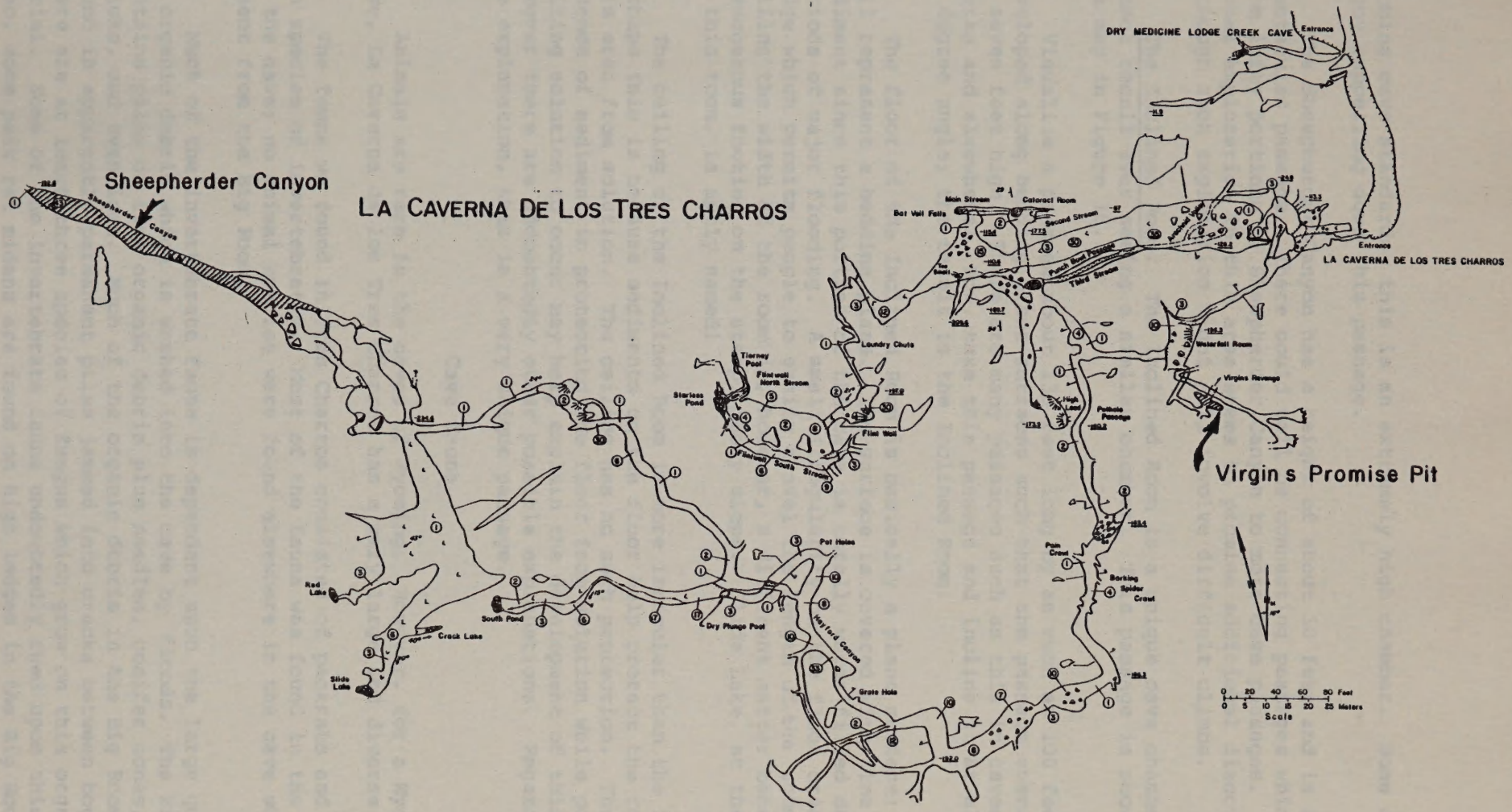


Figure 14. The location of high fissure passages in La Caverna de los Tres Charros.

Wyoming cave standards, this is an extremely high chamber. Some cavers enjoy rappelling down this passage.

The Sheepherder Canyon has a height of about 50 feet and is a rather spectacular passage. There could well be connecting passages which lead from lofty portions of Sheepherder Canyon to more cave passages. Additional exploration in this area seems to promise additional discoveries, although such exploration might well involve difficult climbs.

The Inclined Room. The Inclined Room is a unique cave chamber; we cannot recall ever seeing a similar chamber. This passage is shown on the map in Figure 15.

Visualize a passage about 130 feet long by as much as 100 feet wide developed along bedding plane surfaces such that the passage averaged five to seven feet high. There are many passages such as this in caves in the Ozarks and elsewhere. Now, take this passage and incline it at almost a 45 degree angle; the result is the Inclined Room.

The floor of the Inclined Room is basically a plane surface; it may well represent a bedding plane. The surface is covered with fine textured sediment since this portion of the cave is totally water filled during periods of major flooding. A small irregularity on the floor creates a ledge which permits people to easily travel the length of the room. Travelling the width of the room is, however, a different matter because of treacherous footing on the steep, muddy slope. Slide Lake, at the bottom of this room, is aptly named!

The ceiling of the Inclined Room is more irregular than the floor. Perhaps this is because sediments on the floor help protect the rock in this area from solution. The ceiling has no such protection. The influence of sediment in protecting the floor from solution while permitting ceiling solution to occur may help explain the development of this chamber, however there are undoubtedly other possible explanations. Regardless of the explanation, this is a very unique passage.

Cave fauna

Animals are rare in the caves of Wyoming. However, for a Wyoming cave, La Caverna de los Tres Charros has a very large and diverse fauna.

The fauna we found in Tres Charros consisted of packrats and about ten species of invertebrates. Most of the fauna was found in the Big Room of the cave; no animal species were found elsewhere in the cave which were absent from the Big Room.

Much of the invertebrate fauna is dependent upon the large quantities of organic debris which is washed into the cave by floods. The Big Room contains piles of fine organic debris plus needles, conifer cones, twigs, sticks, and even logs. Much of the organic debris in the Big Room is found in apparently permanent piles jammed into cracks between boulders. There are at least three species of fungus which grow on this organic material. Some of the invertebrate fauna undoubtedly feed upon this fungus. Also, some pack rat midens are found on high ledges in the Big Room and these midens are also a food source for cave animals.

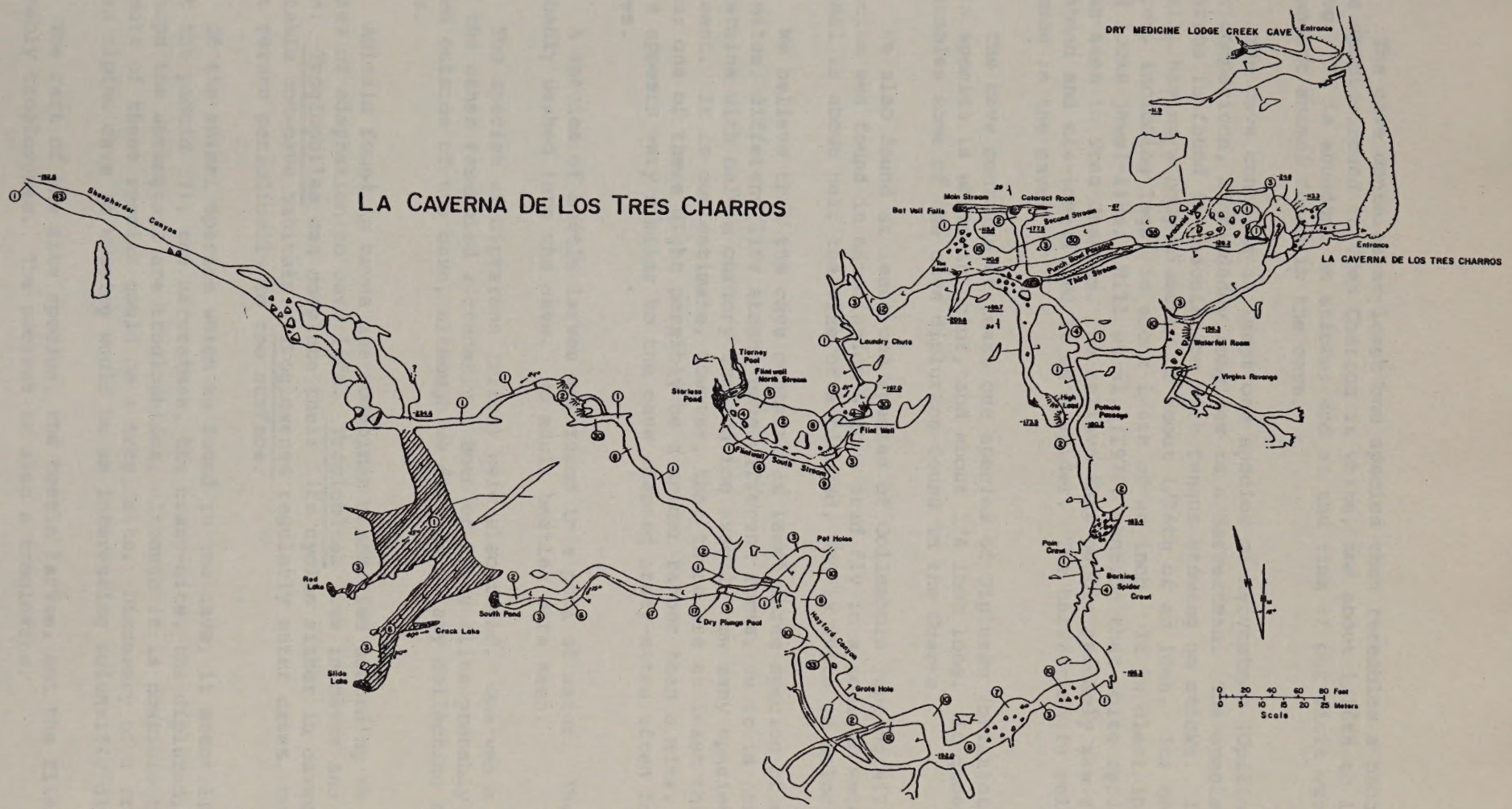


Figure 15. The location of the Inclined Room in La Caverna de los Tres Charros.

The cave contains at least one species that resembles a psocid (louse). The species found in Tres Charros is white, and about 1/16th to 1/8th inch long. It is abundant on sticks, and at the time of our visit was the most abundant animal found in the cave.

The cave contains at least one species of harvestman (Opilionid). For comparison, a grandaddy longlegs is a harvestman. The species in Tres Charros is found in association with fungus growing on sticks. It is very small, having a body diameter of about 1/16th of an inch. Its total diameter, including legs, is about 1/4th of an inch. It is clear in color and looks jewel-like. Hill et al. (1976) mention that white spiders have been seen in Tres Charros. We believe that people probably saw this harvestman and mis-identified it as a spider. The harvestman is relatively common in the cave.

The cave contains at least one species of Dipluran (bristletail). This species is white in color, and about 1/4 inch long. It generally resembles some of the cave diplurans found in the Ozarks.

We also found at least one species of Collembola (springtail). This species was found in association with a dead fly in a pool of water. This animal is about half the size of a pinhead, and is white in color.

We believe that the cave contains at least three species of mites. In mites, different life stages have different forms, so it is hard to determine with only a cursory examination exactly how many species may be present. It is our estimate, however, that there are at least three species; one of these might possibly be a spider rather than a mite. Another mite appears very similar to the cave adapted crazy-mites often found Ozark caves.

A species of beetle larvae was found in a pool of water. They were probably washed into the cave. No adult beetles were seen.

Two species of Dipterans (flies) were also found. One was a gnat, and the other resembled a cranefly. Both of these flies probably are found outside of the cave, although we did not do any collecting to verify this.

Animals found in caves are sometimes classified according to their degree of adaptation to cave life. Troglobites live in caves and nowhere else. Troglophiles can complete their life cycles either in caves or in suitable non-cave habitats. Trogloxenes regularly enter caves, but they must return periodically to the surface.

Of the animal species which we found in the cave, it seems likely that the psocid (?), the harvestman, the crazy-mite, the dipluran, and perhaps the springtail are troglophiles, although it is possible that one or more of these species could be a troglobite. Discovery of a troglobite in an alpine cave in Wyoming would be an interesting scientific discovery.

The rest of the mite species, the beetle larvae, and the flies are probably trogloxenes. The packrat is also a trogloxene.

We have discussed the fauna which we found in Tres Charros with Dr. Thomas Poulson, Department of Biology, University of Illinois at Chicago Circle. Dr. Poulson is a nationally recognized authority on cave fauna. Dr. Poulson told us that white diplurans, harvestmen, crazy-mites, psocids, and springtails are extremely difficult to separate into troglophiles and troglobites. He did not believe that he could help us determine whether the animals we found in Tres Charros were troglobites or troglophiles.

Dr. Poulson suggested sending animals which we collected during our field work (these included two diplurans, two harvestmen, one crazy-mite, and four psocids [?])to Dr. Stuart Peck, Department of Biology, Carlton University, Ottawa, Ontario, Canada. Dr. Peck is a specialist on the adaptation of animals in cold climates to caves. We have written Dr. Peck to see if he would be willing to examine the collected material. BLM will be informed of any findings or conclusions which Dr. Peck may make. Such findings will be made an addendum to this report.

It is possible that the fauna found in La Caverna de los Tres Charros could be of scientific importance. This should be recognized by land managers concerned with the cave. Because of their abundance and well scattered locations, the cave fauna is not likely to be seriously affected by human visitation of the cave. A management action which could have serious impacts on these animals would be the permanent diversion of the surface streams away from the cave system. Such an action is not recommended and in reality it would be very difficult and expensive to construct such a permanent water diversion around the cave.

Hydrology of the cave

As described earlier, there are a number of waterfalls and stream segments within La Caverna de los Tres Charros. The majority of the water found in the cave is derived from the piracy of surface streams.

Monsson (1974) injected one of the rhodamine dyes at the point where Dry Medicine Lodge Creek sinks into the ground near the entrance to Dry Medicine Lodge Cave. Figures 16 and 17 were taken in this area. For purposes of identification, Figure 18 shows the entrance to Dry Medicine Lodge Creek Cave.

The dye which Monsson (1974) injected reappeared at a number of points within Tres Charros (Figure 19). Table 1 summarizes Monsson's positive test results.

Monsson's work (1974) indicated that the various streams found in Tres Charros are not hydrologically separate. The source for at least part of the flow of most or all of the streams in the cave is surface flow from Dry Medicine Lodge Creek. Flow from this surface stream enters the groundwater system near the entrance to Dry Medicine Lodge Creek Cave.

Divergent stream systems, such as those in Tres Charros, occasionally occur in cave systems. Except in delta areas, they seldom occur on the surface. Stream system divergence often occurs when one drainage route has a capacity smaller than the total supply of water available. This is the probable explanation for the divergent stream systems which typify Tres Charros.

Figure 16. Surface stream in Dry Medicine Lodge Creek. The man is standing near the point where the stream disappears underground. The entrance to Dry Medicine Lodge Creek Cave is in the background.

Figure 17. A swallowhole on Dry Medicine Lodge Creek near the entrance to Dry Medicine Lodge Creek Cave.

Figure 18. Entrance to Dry Medicine Lodge Creek Cave.

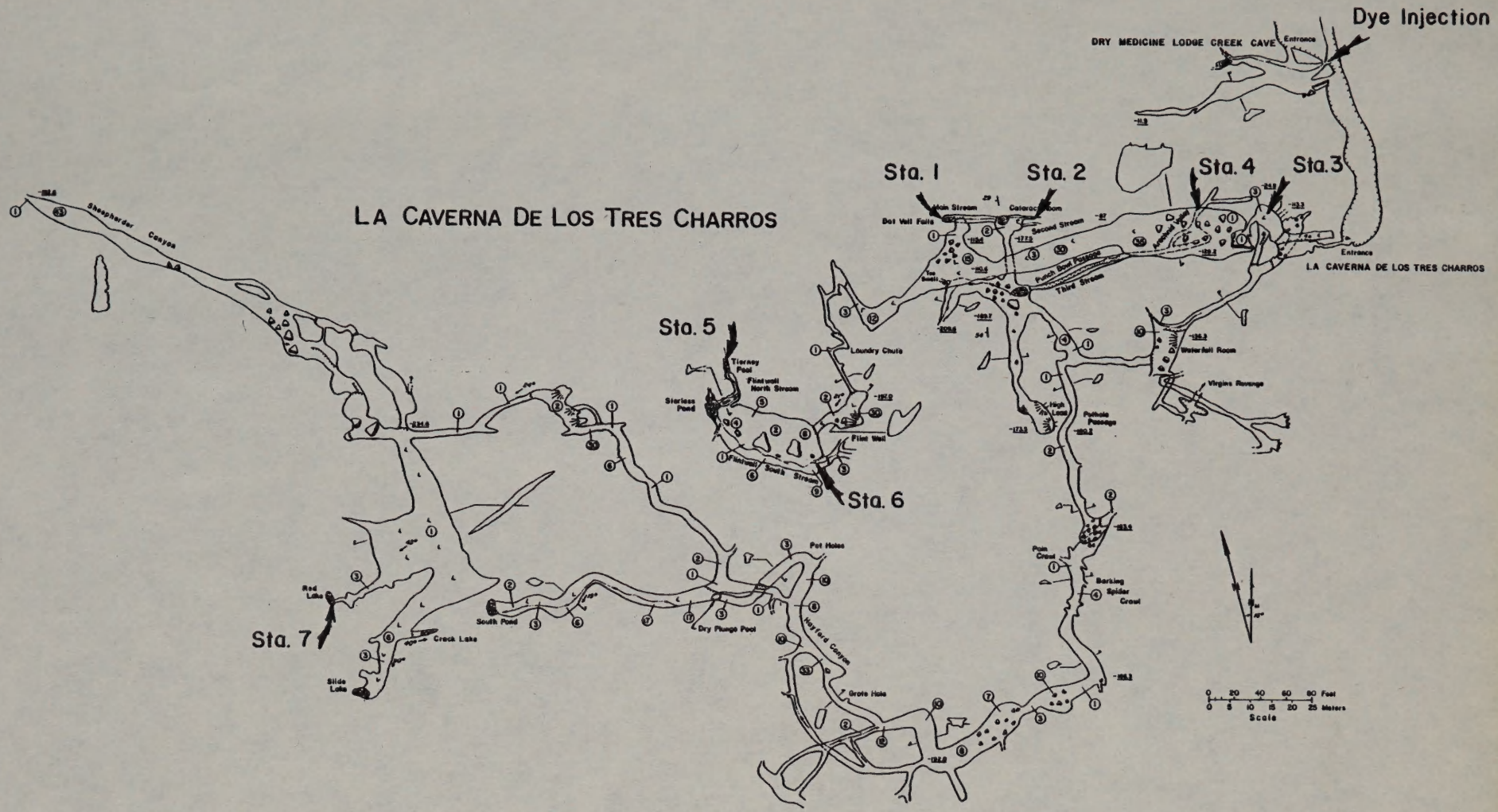


Figure 19. Location of dye recovery points (Monsson, 1974).

TABLE 1

Travel times and distances for dye injected in Dry Medicine Lodge Creek near the entrance to Dry Medicine Lodge Creek Cave. Data from Monsson (1974). Dye injection was apparently made on September 19 or 20, 1974.

Dye recovery point	Time after injection; first recovery (min)	Depth beneath injection point (ft)	Straight-line distance from injection point (ft)	Minimum travel velocity (ft/sec)
Station 1 Bat Veil Falls	16	118	378	23.6
Station 2 Cataract Room (second stream)	19	181	351	18.5
Station 3 2F Falls	19	105	175	9.2
Station 4 (A28)	29	187	387	13.3
Station 5 Flint Wall (North Stream)	30	270	695	23.2
Station 6 Flint Wall (South Stream)	about 60	270	789	about 13.2
Station 7 Red Lake	about 222	300	1120	about 5.0

Note: All dye recovery stations are shown on the map in Figure 20.

La Caverna de los Tres Charros presents an uncommonly dramatic display of divergent underground streams. There are many divergences within the cave. Furthermore, when the flow of Dry Medicine Lodge Creek is large, there are other points where surface streams disappear into the groundwater system. The result is a complex three-dimensional maze of underground streams. Such an outstanding display of the complex nature of flow routes in soluble rocks is the most important natural feature of this cave system.

The sinking point on Dry Medicine Lodge Creek drains an area of about six square miles. Except for periods of peak flow, all of the surface flow from the area upstream of the sinking point enters the groundwater system. Based upon a visual comparison of the quantity of water in the cave stream and the quantity of water disappearing at the sinking point, it appears that most or all of this water passes through Tres Charros.

An unnamed tributary joins Dry Medicine Lodge Creek about 500 feet downstream of the entrance to Tres Charros. This unnamed stream, which we will call Taylor Camp Creek, drains an area of about two square miles. Taylor Camp Creek normally sinks underground a few hundred feet upstream of its confluence with Dry Medicine Lodge Creek. During periods of peak flow, some surface flow reaches the surface channel of Dry Medicine Lodge Creek.

Monsson (1974) reports that he was unable to detect any water from this stream in Tres Charros; he apparently attempted a dye trace, but does not describe it. From other groundwater tracing work he did in the area, we infer that he attempted a visual tracing. Because it is easy to miss visual traces, we should not assume that water disappearing underground from this stream does not appear in La Caverna de los Tres Charros. Further hydrologic work is needed on this issue.

Monsson (1974) reported that the flow of Dry Medicine Lodge Creek upstream of its sinking point was 1.98 cfs on September 20, 1974. During our work, we estimated the flow at this point to be approximately 2.25 cfs on September 6, 1979. Monsson (1974) measured the flow of Taylor Camp Creek near its losing point at 0.39 cfs on September 20, 1974. During our work, we estimated the flow at this point to be approximately 0.33 cfs on September 9, 1979.

Tres Charros is subject to rapid and severe flooding. Flooding occurs when the rate of water inflow to the cave from Dry Medicine Lodge Creek (and perhaps also Taylor Camp Creek) exceeds the rate of drainage out of the cave system. Based upon our field work, it appears that the natural drainage rate of the cave is at least 2.25 to 2.50 cubic feet per second.

Based upon sediment deposits in the cave, water ponds in the cave up to eighty feet deep for substantial periods of time. Most of this type flooding is probably associated with snowmelt runoff. Areas near the various lakes in the cave are subjected to this type of flooding.

During periods when there is heavy inflow to the cave, many and perhaps most of the cave passages are transporting water. Under these conditions, localized areas would be totally inundated. Water flow in other

areas could be so torrential that a person could not traverse the cave passages. Based upon debris marks and the nature of the passages, even if a person were in the Big Room, it would sometimes be impossible to exit from the cave during an underground flood.

Underground flooding is the most serious safety hazard in La Caverna de los Tres Charros. Steps for dealing with this hazard are discussed in the health and safety section of this report, and recommendations are made for a rescue strategy should people be trapped in this cave by flooding.

La Caverna de los Tres Charros extends to a depth of about 300 feet beneath the channel of Dry Medicine Lodge Creek. Except at extremely high flows, the entire flow of Dry Medicine Lodge Creek enters the cave. In addition, it is likely that most of the flow in Taylor Camp Creek also enters the cave and contributes to underground flooding.

The watershed areas for both of the streams is mountainous, and stream gradients are steep. Only a small portion of the area is on BLM lands; most of the area is National Forest. Grazing on National Forest lands is very heavy. As a result of this, the watershed is not able to detain runoff waters as effectively as would be the case under more moderate use levels. An intense rainstorm in the drainage basin for either Dry Medicine Lodge Creek or Taylor Camp Creek would rapidly increase the flow of water entering the groundwater system in Tres Charros.

The drainage basins for both Dry Medicine Lodge Creek and Taylor Camp Creek are roughly rectangular, and both have a length to width ratio of about 3:1. As contrasted with less elongated basins, the peak flow rate from floods would be smaller, but the duration of the flood event would be longer.

The basins for both of the surface streams are generally oriented northeast-southwest, with discharge from the basins occurring at the western end. Because of this orientation, some thunderstorm cells could travel parallel to the basin, thereby producing significant amounts of rainfall over a major portion of the basin area.

For management purposes, it would be very helpful to correlate the volume of water entering the groundwater system with the water problems encountered by explorers in Tres Charros. A technique for collecting this sort of information is proposed later in this report. We strongly recommend that this data be collected. In the interim, however, we have made some estimates of the effects on cave explorers which are anticipated at various streamflow rates (Table 2).

We have examined rainfall frequency data for the area (U.S. Weather Bureau, 1961) and find that a one hour rainfall intensity of 0.4 inches or more occurs on the average of once per year. Two hour duration rainfalls of about one inch are equalled or exceeded about once every 5 years.

Based upon very limited data, we anticipate that summer rainstorms producing enough water to increase the flow of the streams in the area to at least 10 cfs occur about once a year. According to Table 2, such flows would probably create serious hazards for cave explorers. Rainstorms pro-

TABLE 2

Estimates of the likely effects of various streamflow rates on cave explorers in La Caverna de los Tres Charros. Flow rates represent total flow in Dry Medicine Lodge Creek plus Taylor Camp Creek.

Flow rate (cfs)	Anticipated effects on cave explorers
2.5	No significant problems. This represents the approximate volume entering the cave system during field work in September, 1979.
5.0	Would probably not create hazardous conditions for cave explorers. Sinking stream points near Dry Medicine Lodge Creek Cave might not be able to handle this entire volume. As a result, we anticipate that some water would enter the subsurface near the entrance to La Caverna do los Tres Charros.
10.0	Would probably create serious hazards for cave explorers, and could perhaps trap explorers. The area between the Tres Charros entrance and the Big Room could be very difficult (or perhaps impossible) to negotiate. The volume of water cascading down Bat Veil Falls Pit might make the ascent of this pit difficult or impossible.
25.0	Cave explorers would probably be trapped until flood waters receded. Rescue efforts would probably be required.

ducing enough water to increase the flow of the streams in the area to at least 25 cfs would occur about once every two or three years. According to Table 2, such storms would probably trap cave explorers, and rescue efforts would probably be required.

The above estimates, rough as they may be, are intended to help BLM management place the flooding risk in this cave in perspective. The cave will not flood significantly everytime there is a little bit of rain in the watershed area, yet conversely, it does not take a great deal of rain to create major problems. An average runoff of 0.05 inches over the entire watershed would probably create a 10 cfs flood in the cave. An average runoff of 0.17 inches over the entire watershed would probably create a 25 cfs flood in the cave.

HEALTH AND SAFETY

Three classes of health and safety hazards may be associated with visitation of La Caverna de los Tres Charros. The first health and safety hazard category includes those hazards people commonly recognize as associated with cave exploration. These include hazards of loose rocks, the chance of falling down holes, the risk of becoming lost, and the risk of being trapped or drowned by underground floods. The risk of hypothermia is associated with entrapment by underground floods, and will be discussed in conjunction with this hazard.

Two additional classes of hazards are also considered in conjunction with this cave. These classes are not commonly recognized as being associated with cave exploration. The first of these is the risk of contracting histoplasmosis, a fungal lung disease. The second risk is associated with exposure to naturally occurring alpha raidation.

Commonly recognized cave hazards

Loose and shifting rocks. Tres Charros, like essentially all caves, contains some loose and shifting rocks. At least a few such rocks can be encountered in essentially any portion of the cave. Loose rocks which could injure visitors are least abundant in small stream passages because they tend to be removed or stabilized by floodwaters.

There are no areas in Tres Charros where loose and shifting rocks are so abundant or so precariously poised as to represent an unusually significant hazard. However, it is recommended that people entering any cave should be cautioned about loose and shifting rocks.

Becoming lost. La Caverna de los Tres Charros is neither so large nor so complex as to make it likely for someone to become seriously lost. It is possible to become confused for a few minutes, but this is not viewed as a hazard. However, the cave is complex enough that one could not expect to find his way out without a light.

Failure of all lights. Most cave rescues result from the loss or failure of lights carried by visitors. Although this hazard is generally perceived by most visitors, people commonly enter caves with lights of inadequate quality and without an adequate supply of spare lights.

Experienced cavers generally carry adequate lights. Knowledge of the location of Tres Charros is generally restricted to experienced cavers, so the chance of inexperienced people visiting this cave is less than at many of the other caves in Wyoming administered by BLM.

Each person visiting this cave should carry at least two sources of acceptable light. Candles, chemical light-sticks, matches, lighters, flashlights with undependable switches, flashlights with batteries smaller than size D, and gasoline, propane, or kerosine lanterns should not be counted as acceptable lights (although some of these items are sometimes nice to carry). In addition, each flashlight should have new, and preferably long-life type, batteries. Extra new batteries (long-life type) should be carried for at least half of the flashlights in the group.

Falling down pits or climbs. Climbs requiring technical ropework are found at four places in La Caverna de los Tres Charros (Figure 20). BLM should advise visitors as to the nature of equipment and techniques needed to safely negotiate these areas. There are other areas in the cave where explorers might occasionally climb, but we see no way of making practical recommendations for such a scattered activity.

Bat Veil Falls Pit is about forty feet deep. It is a free drop extending from the Big Room to a large ledge at the base of Bat Veil Falls. From the bottom of this pit, one climbs an additional 20 feet down a steep chute (Figure 5) to the Cataract Room. The best anchor point for rigging the drop at Bat Veil Falls is a large rock slab about 12 feet from the edge of the drop. A chockstone at the edge of the drop is apparently sometimes used; it is not a safe anchoring point.

Many people probably rappel down this drop, and then use ascenders to get back up the climb. Since the passage at the top of the climb is only about three feet high, it is awkward and somewhat difficult to get into proper rappel position. Inexperienced people could have problems here. Loose rocks do not present a significant problem on this drop.

The normal descent point in Bat Veil Falls Pit is about 15 feet from Bat Veil Falls; we did not get wet when we descended this pit in September, 1979. However, this could be a treacherous spot when water flows in the cave are greater. A flash flood in the area could increase the water flow down this pit enough that it might be impossible to climb up the pit.

Safe descents of the Bat Veil Falls Pit require at least 75 feet of rope. This is not the sort of climb where a person could ascend the rope hand-over-hand. Either rope or cable ladders, ascenders, or prussick knots are needed to climb back up this pit.

The location of the Laundry Chute Pit is shown on Figure 20. It is a steeply descending climb where approximately 75 feet of belay rope should be used for safety. An experienced climber could negotiate this drop without a rope, but a belay is a prudent measure.

The Inclined Room is tilted at almost a 45 degree angle, and the floor is covered with mud. As with the Laundry Chute Pit, the prudent approach is to belay anyone climbing down to any of the lakes at the base of this room. An injury in this area could create serious rescue problems; with this in mind, cavers need to be particularly careful in this area. A hundred feet of belay rope should be adequate for anything in this room.

The Virgin's Promise Pit is about 100 feet deep, and is apparently a popular free rappel for cavers. The drop does not have any serious loose rock problems. One can apparently reach both the top and the bottom of the Virgin's Promise Pit without having to do any technical climbing. During work in the cave, we reached the bottom of this pit. Some time was spend searching for the passage which led to the top of the pit, but we were unable to decipher the route from the map. Pete Uhl confirmed that there is a route that does not require ropework which bypasses this pit.

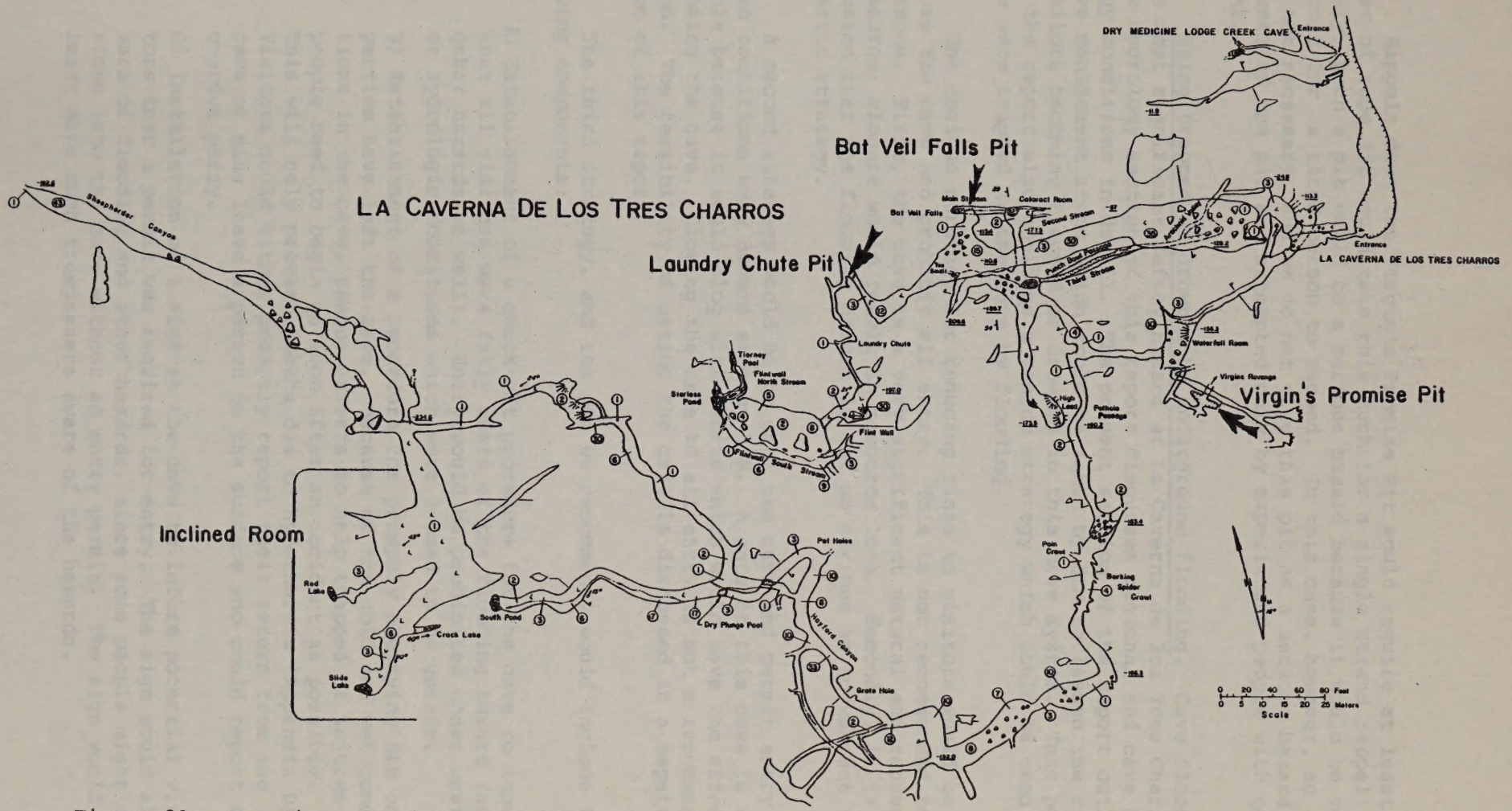
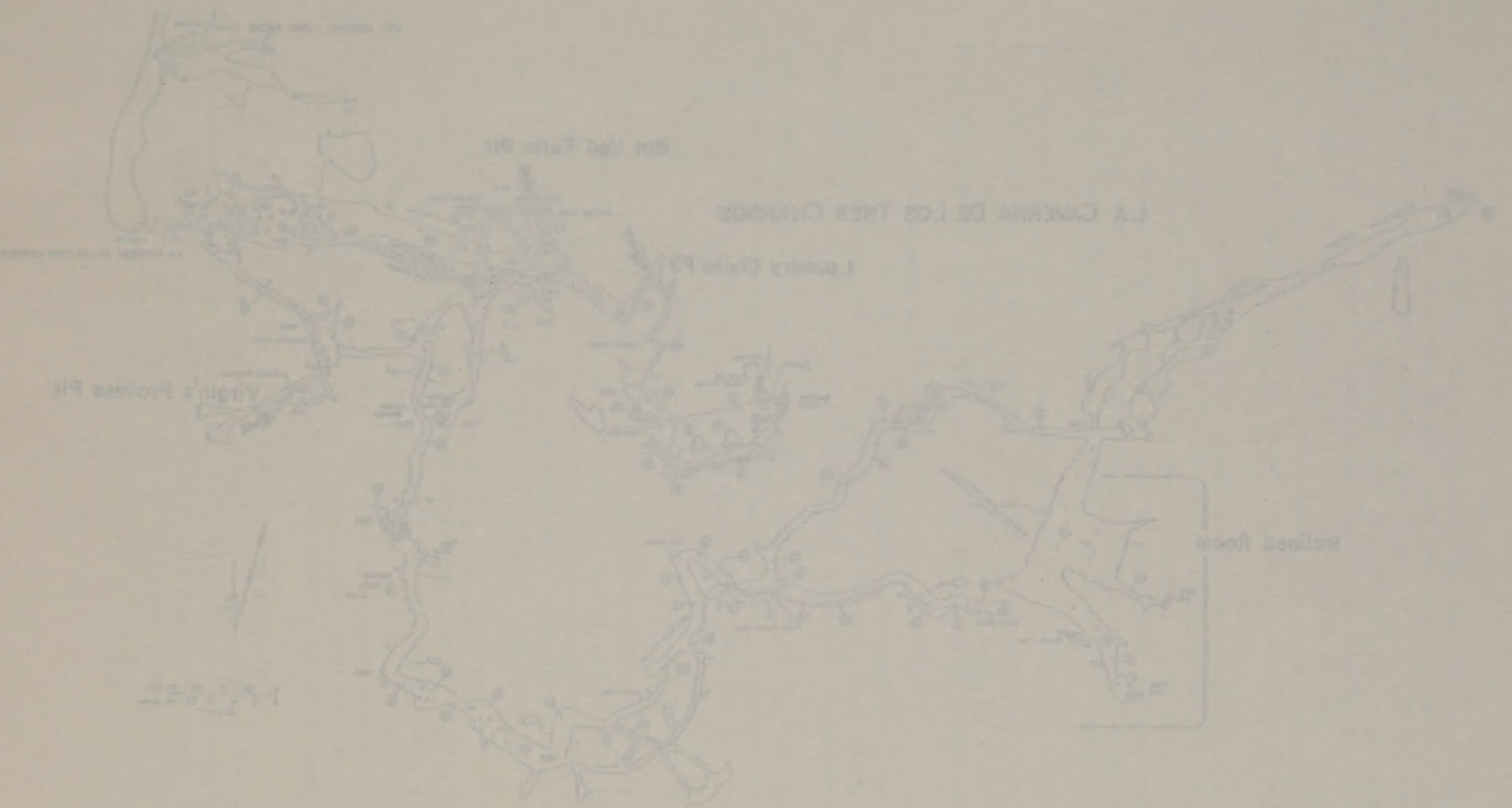


Figure 20. Location of climbs and pits where technical ropework is required or recommended.



Rappels down the Virgin's Promise Pit would require at least 120 feet of rope (it would take this much for a single strand rappel). Normally, such a pit would be a serious hazard because it would be very difficult for a tired person to ascend. In this case, however, an ascent is not necessary, and we do not view this pit as a serious hazard if descents of the pit are attempted only by experienced people with good equipment.

Being trapped or drowned by underground flooding. Cave flooding is the most significant safety hazard at La Caverna de los Tres Charros. The hydrology section of this report discusses regional and cave hydrology conditions in detail. The present section of the report outlines cave management steps which could be taken by BLM to lessen the risk of visitors becoming trapped or drowned in this cave system. This portion of the report also outlines a rescue strategy which could be used if people were trapped in the cave by flooding.

One obvious strategy for reducing risks to visitors would be to close the cave and prohibit all entry. This is not recommended for two reasons. First, the cave is a very significant natural and recreational resource; closure would result in resource loss. Secondly, it is our conclusion that the flooding hazard is not so serious as to warrant this drastic strategy.

A second strategy would be to gate the cave and permit entry only when conditions were deemed safe by BLM. A gate on this cave is not feasible because it would clog with debris which would have the effect of closing the cave. Closing the cave to all entry is not a recommended option. The feasibility of gating the cave is discussed in a seperate section of this report.

The third strategy, and the one we recommend, would include the following components:

A) Establishment of a check-out procedure for the cave to insure that all visitors were fully aware of the flooding hazard (and other hazards as well). Entry would be prohibited under weather or hydrologic conditions which were deemed to be unsafe.

B) Establishment of a procedure for promptly notifying BLM once parties have left the cave. Because of the cold and wet conditions in the cave, rescue efforts to help trapped or injured people need to begin as soon after an accident as possible. This will help prevent deaths due to hypothermia (Appendix D). Visitors could either promptly report their return from the cave or else leave a person on the surface who could report an overdue party.

C) Installation of a sign at the cave to inform potential visitors that a permit was required for entry. The sign would also warn of flooding and other hazards, since some people might continue into the cave without an entry permit. The sign would at least make such trespassers aware of the hazards.

D) Involvement of visitors in a program to make them more aware of the flooding hazard. Specifically, we recommend that staff gages be installed on both Dry Medicine Lodge Creek and Taylor Camp Creek (see "Recommendations for additional investigations"). Visitors would be asked to read the staff gages and record any inconvenience or hazard related to flooding which they found in the cave during their visit. Such information would be recorded by BLM. Ultimately, visitors could anticipate the extent of underground flooding problems simply by reading the staff gages. This approach is similar to that used successfully for boaters on some whitewater streams.

E) Maintenance and possible expansion of the existing survival cache in the cave. All visitors would be informed of its location, and those in the area would be asked to check its condition and report any problems to BLM.

F) Development of a rescue plan for people trapped by flood waters.

The recommended management strategy would decrease the liklihood of visitor entrapment or death because of underground flooding. However, it would not prevent these dire consequences for the following reasons:

1. Flooding in Tres Charros occurs very rapidly. Data from Monsson (1974) indicates that cave flooding could begin in 15 to 30 minutes after an increase occurred in the flow of Dry Medicine Lodge Creek (Table 1).

2. In order to get out of the cave during a flood, one would have to travel upstream. As a result, it is impossible to outrace the floodwave.

3. Cavers, including those in organized groups, have not demonstrated an ability to make prudent decisions about cave flooding. Drowning in underground floods (or hypothermia among trapped people) is the major cause of cave-related deaths in the United States. There are several explanations for this situation.

   A) Most cavers are young, and thus lack a base of experience and prudence.

   B) Caving is often a social activity where cutting safety margins very thin is viewed as "sport". Appendix A includes an article by a caver trapped by a flood in a Georgia cave; he and his party entered the cave during a rainstorm and after an employee of the administering land management agency had discussed cave flooding with him. We believe that his attitude (Beck, 1979) and the criticism by Guy (1979) [also included in Appendix A] will be of interest to readers of this report.

   C) Most cavers are from urban areas, and do not have a good appreciation of how rapidly major storms and floods can develop in wildland areas.

4. Cave flooding is not a common problem in the western U.S. As a result, cavers in this region are less accustomed to dealing with this hazard than are cavers in the eastern U.S.

5. Trips to Tres Charros cannot be easily diverted to other caves. As a result, a group arriving at the cave and finding poor weather conditions is likely to gamble that flooding will not occur. Similar gambling led to the Beck party being trapped in a Georgia cave (Appendix A).

6. Hypothermia is a serious hazard among people who are trapped in caves, yet most cavers do not fully appreciate its significance (Appendix D).

7. When drownings do occur in caves during floods, it is sometimes because people panic and try to swim through flooded passages. In other cases, victims overestimate their ability to stand in swift water.

There is a handy rule-of-thumb used by people involved in stream gaging work which could be applied to caving. If the velocity of the water (in feet per second) multiplied by the depth of the water (in feet) is equal to a value of 10 or more, a person will be swept off his feet. In a cave situation, anytime this value equalled or exceeded six, it would be essentially impossible to negotiate a cave passage. There are a number of places in Tres Charros where it would be impossible to negotiate passages once the water became more than a couple of feet deep. This rule-of-thumb value of six would be a useful value to include in any printed material designed to acquaint cave visitors with the hazards in Tres Charros.

Preliminary rescue strategy for people trapped in the cave by flood waters. The rescue of people from flooded caves is generally a matter of waiting at the entrance until floodwaters naturally recede, and then sending in a search and rescue party. In most cases, there is little that can be done to speed the recession of flood waters in the cave passages. This is not the case at Tres Charros.

Flooding in Tres Charros occurs because water flows into the cave from Dry Medicine Lodge Creek (and probably from Taylor Camp Creek also) at rapid rates. Cavers could be trapped in the cave for two reasons. First, the rate of water inflow to the cave could be so rapid as to make it impossible to traverse certain passages on the route out of the cave. Secondly, the rate of water flow into the cave could exceed the drainage capacity of the cave; this would cause water levels deep in the cave to rise. Based upon our work in the cave, the first mechanism is the one most likely to trap cavers.

If fatalities should occur in the cave due to cave flooding, they would most likely result from people wading in swift water, trying to swim through a flooded passage to escape the cave, or from hypothermia. These causes explain most of the deaths which have occurred due to cave flooding.

The average temperature in Tres Charros during our field work in September, 1979 was 43 degrees; it may be lower at other times of the year. The low temperature makes the risk of hypothermia serious for people trapped in the cave by floods. The risk is greatly increased if the people are wet. Rescue efforts need to be both prompt and effective (Appendix D).

Any steps which would reduce the rate at which water enters the cave system would reduce the period of time that people would be trapped. In an emergency, we believe that stream flow in Dry Medicine Lodge Creek and Taylor Camp Creek could be diverted away from the points where it now sinks. Keeping this streamflow on the surface would rapidly end underground flooding and permit search and rescue efforts to begin in the cave.

Significant quantities of diverted surface streamflow could not be permitted to enter the subsurface at other points. First, this would not solve the underground flooding problem. Second, water entering the ground at other points could possibly flood portions of the cave where trapped people had sought refuge. Therefore, merely diverting water for a short distance around existing sinking points is not a recommended approach.

A diversion program which could be constructed and put into operation in an emergency is as follows.

1. A small coffer dam could be constructed about 50 feet upstream of the entrance to Dry Medicine Lodge Creek Cave.

2. An artificial channel could be run from the coffer dam for about 650 feet to an old logging road near the confluence of Dry Medicine Lodge Creek and Taylor Camp Creek. There are many down trees in this area which would have to be moved. Plastic sheeting or irrigation ditch liner would need to be placed along most of this channel.

3. With a dozer, the old logging road which parallels Dry Medicine Lodge Creek could be sloped inward enough that it would carry the flow of the stream. Water could be diverted along this road to about the west line of section 5 without a great deal of effort.

4. Using a coffer dam, water in Taylor Camp Creek could be diverted into the old logging road which runs parallel to this stream. This water would ultimately be fed into the diversion of Dry Medicine Lodge Creek.

For such a diversion program to work properly, it would be necessary to completely construct the diversion channel for Dry Medicine Lodge Creek before closing a coffer dam. After this was done, work should begin on Taylor Camp Creek. We reiterate that merely diverting water for a short distance around an existing sinking point is not a recommended approach. If this were tried, we believe that the diverted water would quickly sink into the ground at another point. If diversions were constructed, they should be continually inspected to insure that no significant leakage points had developed. Any subsurface leakage should be rapidly repaired.

The proposed rescue diversion would require the sort of manpower, heavy equipment, and organization typically involved in a major fire. After notification that a party was trapped in the cave by flooding, we would expect it to take at least 18 to 24 hours before the stream diversion could be completed and the cave could be entered by a search and rescue team. BLM personnel familiar with construction and fire mobilization could undoubtedly make better time estimates than we can; our attempt has been to describe the work needed in order to divert the stream in such a way as to reduce the cave flooding.

It is our conclusion that hypothermia represents a serious hazard for people trapped in the cave by flooding. In view of the cave temperatures and the liklihood that trapped people would be wet, deaths due to hypothermia could well occur in less than the 18 to 24 hours it would take to construct the stream diversion. A party of four teenagers trapped by flooding in a Missouri cave apparently died of hypothermia within about 24 hours of the time they became trapped. The temperature in this cave was 58 degrees; the temperature in Tres Charros is about 43 F. However, there have been several more encouraging cases. In general, parties which have stayed dry, avoided panic, and conserved their energy have survived underground entrapment. One party in Europe was trapped in a very cold cave for six days before floodwaters receded and they could be helped from the cave; this entire party survived.

Cave visitors should be advised to seek high, dry passages in the event of flooding. They should all know the location of the survival cache in the Waterfall Room. In addition, each person should be required to carry with him a dry set of warm clothes (preferably including woolen longjohns). In the event of flood entrapment, people should stay dry, huddle together with others to conserve heat, and maintain enough periodic activity to prevent serious chilling. They should realize that failure to report their safe exit from the cave will lead to rescue efforts, and that they should anticipate rescue within a couple of days. It is our conclusion that even if people are trapped in this cave by floods, they will survive if they take prudent actions.

In accordance with the contract under which this investigation was conducted, we prepared a draft of this report for review by BLM personnel. As a result of this review, three important questions dealing with cave flooding were raised. These questions are specifically addressed below.

Question 1: In view of the flooding hazards in this cave, some land managers might conclude that the cave should be closed to visitation. We would appreciate your thoughts on this, and any recommendations which you might make.

We strongly recommend that the cave not be closed to visitation for two reasons. First, the cave is a very significant natural and recreational resource. Closure of the cave would result in the loss of resources. Secondly, the flooding hazard is not so serious as to warrant such drastic management action.

The recommendations we have made for management actions to make visitation of this cave safer would greatly lessen the risks to which visitors

would expose themselves. With the adoption of such management actions, it is our conclusion that the resources of this cave could be used at an adequate level of safety. We view the recommended rescue strategy as a component of the safety program. The rescue strategy was developed not because we expect it to be used, but because we believe that it should be available in case it is needed.

Question 2: If a party were trapped in the cave by a flood, it would take 18 to 24 hours to mobilize equipment and construct bypass channels for surface streams. If a party were trapped in the cave by a relatively small flood, should the diversion be constructed, or should BLM expect the water level in the stream to drop naturally within 18 to 24 hours?

In some cases, the natural recession rate of the stream will be rapid enough that the cave could be entered before the bypass was completed. In such cases, the mobilization and construction would not have been needed. However, we recommend that mobilization of equipment and construction of the channel bypasses be started as soon as BLM learns that someone is trapped in the cave by flooding. The logic behind this recommendation is as follows:

1. In mountainous terrain, rainstorms (particularly thunderstorms) are very spotty. As a result, it is hard to tell exactly how much rain was received in a basin, and how it was distributed. This makes estimation of flood recession rates very inaccurate. As viewed from the cave, two storms might appear very similar, yet the resulting duration of cave flooding could vary dramatically. Estimates of the duration of flooding could easily be very wrong.

2. The cave is cold, and hypothermia is a real threat. Shortening the flood duration (by the recommended construction) could potentially make a great deal of difference for people trapped in the cave.

3. A second rainstorm could occur while people were trapped in the cave, and this could result in a second flood. This would greatly delay rescue if people were relying solely upon natural recession rates.

4. The people trapped in the cave may require rescue. If the stream diversions were in place, they would undoubtedly make underground rescue efforts easier.

5. If people were trapped in the lowest portions of the cave, the construction of surface stream bypasses would lower water levels deep in the cave much more rapidly than would be possible under natural recession rates. In most cases, rescue workers could not be certain that people were not trapped in the lowest portion of the cave.

Question 3: There are ponds in the cave where water levels fluctuate as much as 80 feet. Could visitors to the cave be trapped by rapidly rising water levels in these ponds?

Yes, it is possible. The quickest way to reduce water levels from this type of flooding would be to construct the surface stream bypass channels. Once water flow into the ponds was curtailed, the natural drainage of the ponds should lower water levels rapidly. It is possible

that some siphons might remain in some of the connecting crawlways; these might require bailing by rescue workers.

Management recommendations on commonly recognized cave hazards. Based upon the foregoing discussion, we have developed the following management recommendations for the commonly recognized cave hazards.

1. People visiting any BLM cave should be cautioned about slippery surfaces, loose and shifting rocks, the possibility of becoming lost, the need for carrying adequate lights, and the risk of falling off boulders or down pits. Existing BLM "Safety Rules for Little Mountain Caves" (form W-01-6227-5), which is given to people registering to visit Horsethief Cave, provides this sort of general cautioning.

2. Hazards associated with loose and shifting rocks in La Caverna de los Tres Charros do not represent an unusually significant hazard. We believe a general cautioning (as in recommendation 1) is adequate.

3. The hazard of becoming lost is not unusually significant in Tres Charros. Should it occur, it would almost certainly result from the failure of lights carried by the party. We believe a general cautioning (as in recommendation 1) is adequate.

4. Visitors to Tres Charros should be advised that the cave is of such size and complexity that lights of good quality as well as spare lights are needed for safe exploration. People planning to explore the cave should carry at least two sources of acceptable light. Candles, chemical lightsticks, matches, lighters, flashlights with undependable switches, flashlights with batteries smaller than size D, and gasoline, propane, or kerosine lanterns should not be counted as acceptable lights. In addition, each flashlight should have new, and preferably long life type, batteries. Extra new batteries (long life type) should be carried for at least half of the flashlights in the group.

5. Visitors to Tres Charros should be cautioned about the four areas where ropework is required or recommended. Recommendations for the equipment needed should be given to visitors. All visitors to the cave should be familiar with technical ropework as commonly done in caving or mountaineering.

6. The danger of being trapped or drowned by underground flooding is the most significant safety hazard at La Caverna de los Tres Charros. People could either drown or die of hypothermia. The flooding and entrapment hazards can be reduced by a management strategy which includes the following components.

A. Starting of a check-out procedure to insure that visitors are aware of the hazards. Entry to the cave would be prohibited under unsafe conditions. Visitors should be prepared to wait out a flood in a high, dry portion of the cave, and should have adequate equipment for such a wait.

B. Establishment of a procedure for promptly notifying BLM once parties have left the cave. As an alternate, one person could be left on the surface to report overdue parties.

C. Installation of a sign at the cave to inform visitors that a permit was required for entry. The sign would also warn of flooding and hypothermia hazards, and would thus insure that even trespassers were aware of these hazards.

D. Involvement of visitors in a program to make them more aware of the flooding hazards. The program would involve developing a correlation between streamflow volumes on the surface and flooding conditions in the cave.

E. Maintenance of the existing survival cache in the cave. In addition, each person visiting the cave should be required to carry with him a dry set of warm clothes (preferably including woolen longjohns).

F. Development of a rescue plan for people trapped by flood waters. A hydrologic strategy for lowering floodwaters in the cave to permit search and rescue is discussed in detail in this report, but this represents only a portion of the recommended rescue plan.

Commonly unrecognized cave hazards

Histoplasmosis and other lung diseases. Histoplasmosis is a lung disease associated with inhaling spores of the fungus Histoplasma capsulatum. Although infection is common (Craigle, 1976), there is generally either no detectable illness or only mild respiratory symptoms. However, there is a progressive type of the disease which is often fatal; this most commonly involves an intense exposure to the spores of Histoplasma capsulatum.

Histoplasmosis is endemic to certain areas of the United States, and in some tropical regions as well. Positive histoplasmin skin tests indicate that 80% of the population in the Mississippi-Missouri-Ohio River Valleys have been affected (Craigle, 1976). In contrast, Histoplasma capsulatum has to date been reported at only one site in Wyoming. The site is Spirit Mountain Caverns.

Because histoplasmosis is of significant concern at Spirit Mountain Caverns, it was considered in detail in our report on that cave (Aley and Aley, 1979). A copy of the histoplasmosis discussion from the Spirit Mountain report is incorporated as Appendix B in this report on Tres Charros; readers wishing detailed information on this disease should consult this appendix.

Spores of Histoplasma capsulatum have been found only in association with bird droppings and bat guano (Aley and Aley, 1979). They have apparently never been found in packrat droppings. Since there are neither bird droppings nor bat guano in Tres Charros, it seems unlikely that the samples which we collected for culturing will prove positive for the spores of Histoplasma capsulatum.

In conjunction with our investigations at Tres Charros, we collected five samples for histoplasmosis culturing from within the cave (Figure 21). Table 3 tabulates data on these samples. The samples were given to Mr. Wayne Holm of the Cody office of BLM for shipment to the Center for Disease Control, U.S. Public Health Service, Atlanta, Georgia. Once we learn the results, we will analyze them and prepare an addendum to this report in which we will recommend any management actions which appear prudent. We anticipate that the samples will be negative for Histoplasma capsulatum; if this is the case, then no management actions are necessary, and we see no reason to caution visitors to La Caverna de los Tres Charros about this possible hazard.

Management recommendations on histoplasmosis. Since neither bat nor bird guano are present in this cave, it seems unlikely that histoplasmosis will successfully be cultured from samples collected from this cave. Based upon the information available, we recommend the following management actions.

1. Histoplasmosis should not be considered a health or safety hazard in this cave, and no warning to visitors is necessary.

2. The results of Histoplasma capsulatum culturing of samples collected in this cave are not yet known. When this analysis is completed by the Center for Disease Control (CDC), we will review the data and prepare an addendum to this report. This addendum will include any additional management recommendations warranted by the CDC data.

Naturally occurring alpha radiation. A detailed discussion of the cave radiation issue (which includes an assessment of the risk, recommendations for management actions, and existing National Caves Association precautionary health standards for alpha radiation exposure in caves) is found in Appendix C. We suggest that this information be read before reading the detailed information included below on Tres Charros.

Alpha radiation concentrations measured in Tres Charros are tabulated in Table 4. Figure 22 is a map of the cave on which sampling locations are shown. Sampling was conducted at stations 1 through 6. All of these, except for station 3, were at locations specified in the contract. Sampling at station 7 (see Figure 22) was also specified in the contract; however, it was impossible to reach this station due to a rock and gravel blockage of the passage leading into this area in the vicinity of the Laundry Chute. Station 3 was selected to replace station 7; station 3 was located near station 7, and is probably representative of the alpha radiation concentrations which exist in the vicinity of station 7.

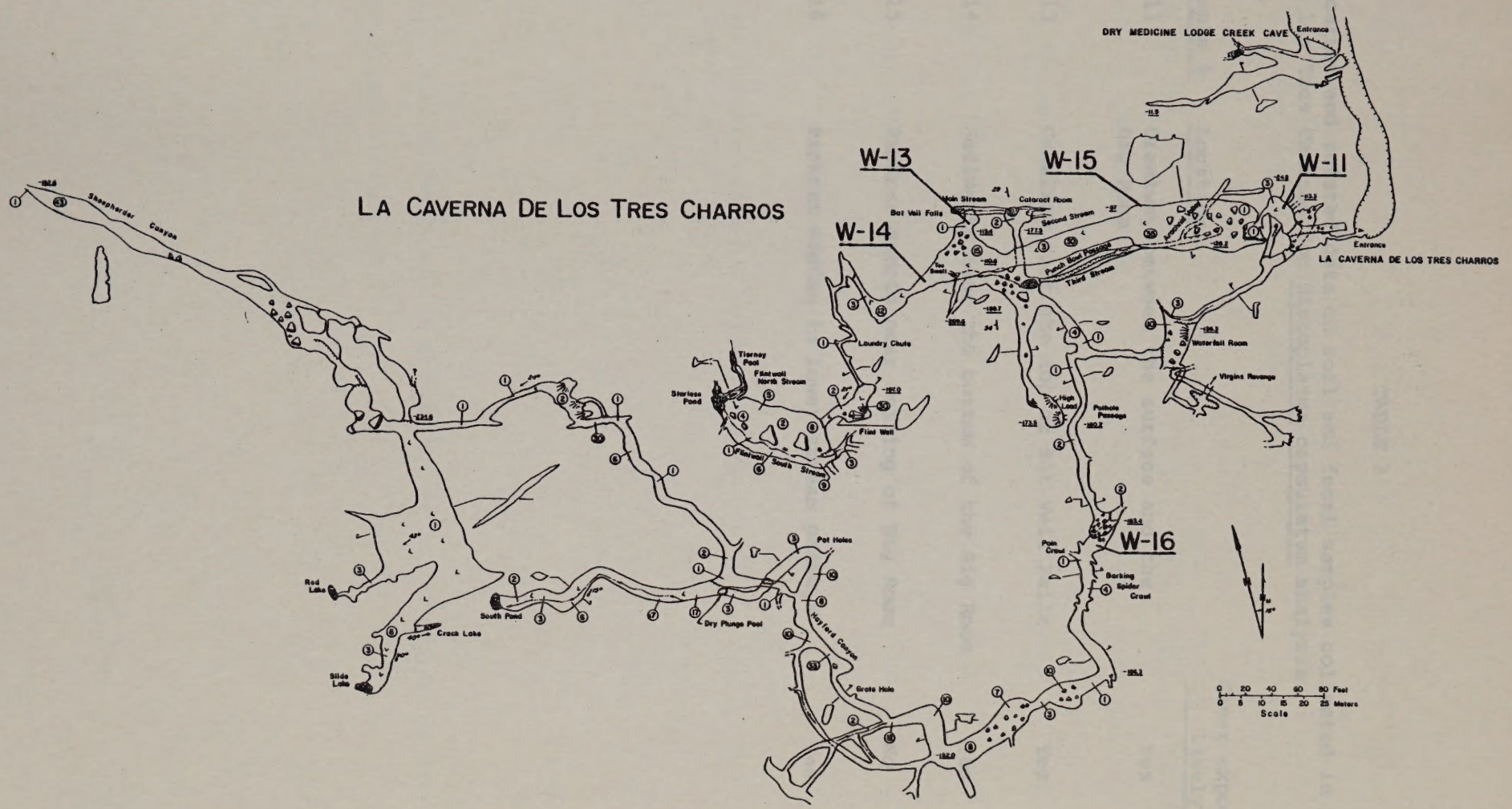


Figure 21. Location of sample sites for Histoplasma capsulatum.

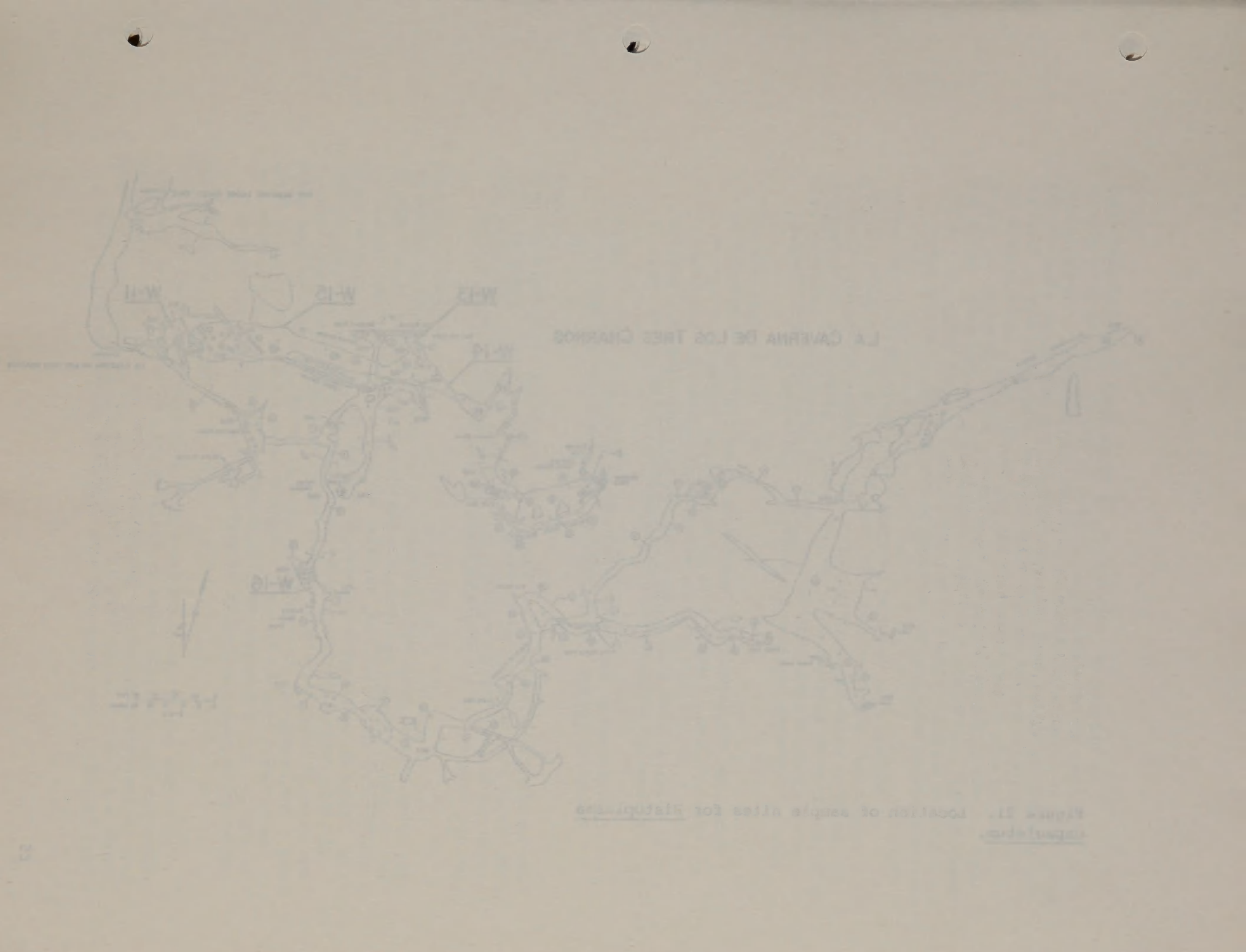


TABLE 3

Location and related data on soil and fecal samples collected in La Caverna de los Tres Charros for *Histoplasma capsulatum* analysis.

Sample #	Location	Caver exposure likely?
W-11	Crawlway between the surface and the Big Room	Yes
W-13	Crawlway near the top of Bat Veil Falls	Yes
W-14	Sediments near the bottom of the Big Room	Yes
W-15	Packrat debris near ceiling of Big Room	No
W-16	Packrat midden in lower stream passage	Yes

TABLE 4

Results of September 8, 1979 alpha radiation and air temperature monitoring in La Caverna de los Tres Charros. Radiation values are in working levels, temperatures are in degrees F.

Station and Location	Time	Radon dgts.	Thoron dgts.	Total	Temp.
1 30 ft. from entrance	17:55	0.01	0.00	0.01	41
2 Lower portion of Big Room	17:22	0.16	0.02	0.18	43
3 Laundry Chute	17:09	0.12	0.01	0.13	43
4 Lower Pothole Passage	15:59	0.10	0.02	0.12	42
5 Lower Stream Passage	15:43	0.08	0.02	0.10	44
6 Intersection of major passages Lower Hayford Canyon	15:30	0.08	0.01	0.09	43
mean		0.09	0.01	0.10	42.7

Note: Airflow during all measurements was moving out of the cave.

Abbr.(dgts. = daughters)

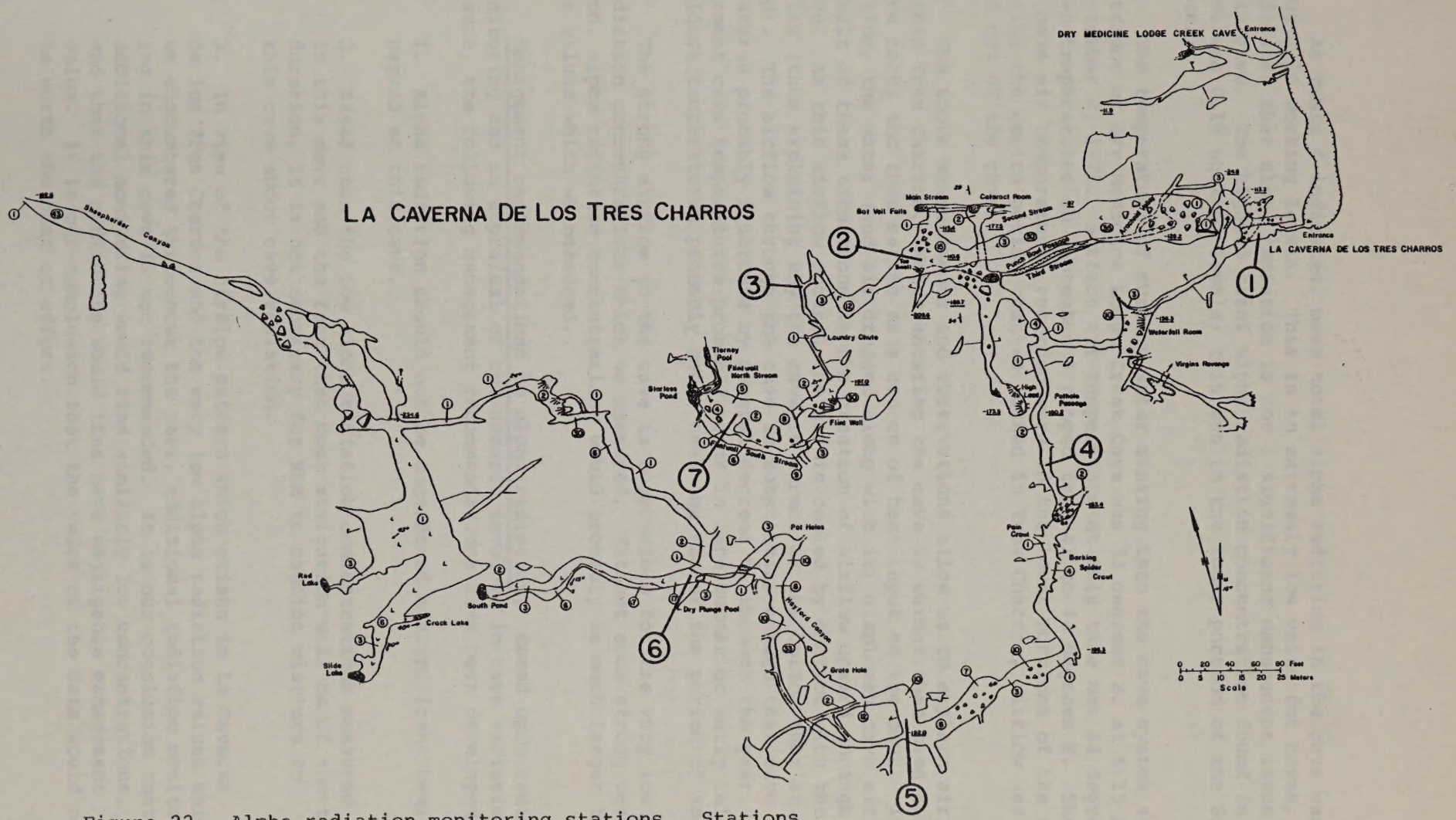
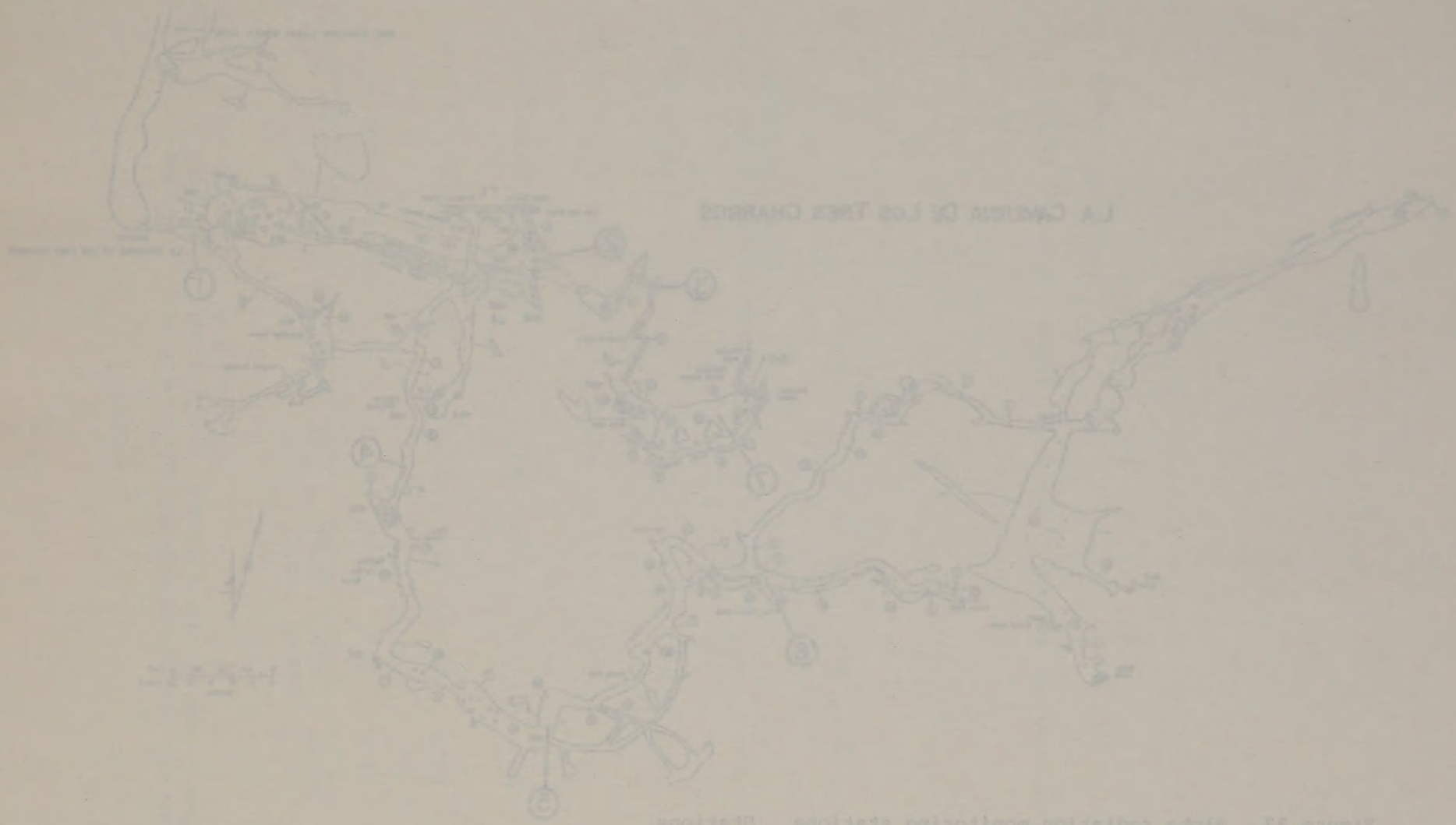


Figure 22. Alpha radiation monitoring stations. Stations 1 through 6 monitored during 1979; station 7 inaccessible due to passage blockage in the Laundry Chute area.



As Table 4 indicates, mean total alpha radiation in the cave was about 0.10 working levels. This is an extremely low value for caves, and indicates that alpha radiation is not a significant management issue at this cave. The highest total alpha radiation concentration found in the cave was 0.18 working levels; this was in the lower portion of the Big Room.

The temperature of surface water sinking into the cave system at the entrance of Dry Medicine Lodge Creek Cave was 53 degrees F. at 6:15 pm on September 8, 1979. Surface air temperature at this time was 54 degrees. Cave temperatures on September 8 ranged from 41 to 44 degrees F. The warmer cave air temperatures recorded were in the lower portions of the cave. During the entire period that we worked in Tres Charros, airflow was upward and out of the cave.

The above measurements and observations allow us to explain airflow within Tres Charros. Water entering the cave is warmer than cave air or cave rock, and thus serves as a source of heat input to the cave. In addition, the water (and air dragged along with it) displaces cave air. The result of these situations is the creation of airflow upward through the cave. As this airflow occurs, the air is cooled by contact with the cave walls (thus explaining why the cave is warmer at the bottom than at the top). The airflow through the cave is substantial enough that cave temperatures probably fluctuate by several degrees F. through the year. The warmest cave temperatures probably occur in late summer or early fall; the coldest temperatures probably occur near the end of the period of snowmelt.

The strong airflow in the cave is responsible for the very low alpha radiation concentrations which we measured. Without such strong ventilation, alpha radiation concentrations would probably be much larger than the values which we measured.

Management recommendations on alpha radiation. Based upon radiation monitoring and an appraisal of the hazards involved in cave radiation exposure, the following management recommendations have been developed.

1. Alpha radiation should not be considered a significant health hazard at this cave.

2. Based upon the low alpha radiation concentrations measured in this cave and the fact that most visitation will be of short duration, it is not necessary for BLM to caution visitors to this cave about cave radiation.

3. In view of the airflow pattern which exists in La Caverna de los Tres Charros and the very low alpha radiation values which we encountered throughout the cave, additional radiation monitoring in this cave is not recommended. It is our conclusion that additional monitoring would find similarly low concentrations, and that the monitoring would thus have negligable management value. It is our conclusion that the value of the data would not be worth the cost or effort.

FEASIBILITY OF GATING THE CAVE

It is our conclusion that controlling access to this cave is a desirable goal. Access control is needed to insure that visitors are adequately informed of the hazards present in this cave, and that people do not visit the cave during times when floods are likely. Access control is not needed to protect the cave resource; the cave does not contain delicate features which could readily be damaged.

There are two places in the cave where a gate could possibly be located. These are 1) at the entrance, or 2) at a point between the entrance and the Big Room.

During snowmelt periods and after major rains large volumes of water enter Tres Charros. This water carries large amounts of debris, including some rather large logs. Both of the gate locations are at points which are filled with water during floods. In such sites, gates that could keep people out of the cave would quickly trap debris and result in the plugging of the passage. This plugging could be substantial, and could well include not only logs and sticks, but also rocks and gravel. Any gate would have to be cleared after each major storm; at times this could involve a great deal of work. Depending upon the location of the gate, it is possible that plugging could be so severe as to permanently close the cave.

Plugging of the gate could well result in the floodwaters opening other entrances to the cave. Under these conditions, people might well be able to bypass the gate. It is possible that a new entrance route between the surface and the Big Room would be characterized by unstable rocks, and would thus make visitation of the cave more hazardous. Also, a new entrance route would defeat the purpose of the gate.

It is our conclusion that a gate is not feasible for La Caverna de los Tres Charros. Approaches other than gates will have to be used to control access to this cave. We recommend the following approaches.

1. Local cavers and caving clubs should be informed that permits are required for each visit to this cave, and that these permits are required because of safety considerations.

2. Visitors to other BLM caves (such as Spirit Mountain Caverns and Horsethief Cave) should be informed in writing on their permits that permits are also required for visits to La Caverna de los Tres Charros. We believe that this will insure that most active cavers are aware of the permit requirement for Tres Charros. It could also be helpful in prosecuting people who enter Tres Charros without a permit.

3. A sign should be placed at the entrance to La Caverna de los Tres Charros informing people that permits are required for cave entry. Recommendations for the information to be included on this sign are made in the "General cave management conclusions and recommendations" section of this report; this is the next section.

GENERAL CAVE MANAGEMENT CONCLUSIONS AND RECOMMENDATIONS

1. La Caverna de los Tres Charros is a large cave with state significance. The cave contains some fine underground waterfalls and stream passages, and provides an excellent display of complex underground drainage. The cave is a significant natural resource.

2. Tres Charros is a very appealing cave for cave explorers. The cave contains both interesting and scenic natural features. In addition, the cave is both interesting and challenging for explorers. Additional passage discoveries are likely.

3. The cave contains a cave fauna which, for such a northern climate, is both large and diverse. We are presently uncertain if any of the species found in the cave are actually obligatory cave animals (troglobites), or whether they are merely species also found in outside environments. The cave fauna may be of scientific interest. The cave fauna is not highly susceptible to damage from human use of the cave.

4. Neither alpha radiation nor histoplasmosis appear to represent significant health hazards in this cave.

5. The pits and climbs in the cave represent a potential safety hazard for inexperienced or careless visitors. Experienced and properly equipped parties should encounter no major problems if they use reasonable care and safety precautions.

6. Cave flooding represents the most serious hazard which could be encountered by visitors. The cave floods rapidly and visitors could easily be trapped. There are areas in the cave where people could escape from floodwaters. The only time people would be likely to drown would be if they tried to traverse flooded passages or passages with swift flowing water.

Hypothermia is a serious threat to cavers trapped by cave flooding. This threat would be greatly lessened if each caver were required to take a spare set of warm, dry clothes in the cave with him. In addition, the survival cache in the Waterfall Room could be of lifesaving importance to trapped cavers.

If people were trapped in the cave by floods, the duration of the flooding could be reduced by diverting surface streams so that they did not contribute water to the cave system. The section of this report entitled "Preliminary rescue strategy for people trapped in the cave by floodwaters" deals with this issue and the techniques which could be used. A substantial amount of work and expense would be involved in such a rescue effort, but it could well mean the difference between life and death for those trapped in the cave.

Even though cave flooding is a serious hazard, it is our conclusion that it is not so significant as to warrant closure of the cave to visitation. We believe the risk can be mitigated by warning visitors and making them aware of the hazard, prohibiting visitation when floods are likely, requiring visitors to have adequate clothing to survive a period of entrapment, and by developing a well conceived and well coordinated rescue plan.

7. We recommend that a check-out procedure be established for visitors to this cave; the check-out should be primarily designed to acquaint visitors with the hazards in this cave and with steps that visitors can take to make their visit a safe and pleasant one.

8. A sign should be placed at the entrance to La Caverna de los Tres Charros informing people that permits are required for cave entry. The sign should also warn visitors that the cave is subject to rapid and dangerous flooding, and that parties trapped by flooding may be forced to spend several days before they could be rescued. Potential visitors should be advised to carry an extra set of warm, dry clothes in the event they become trapped by underground flooding.

The sign should caution potential visitors that the cave contains pits and climbs which require specialized equipment and techniques. The sign should state that some of the pits are too deep to be climbed hand-over-hand up ropes. Finally, we recommend that the sign state that a primary purpose of the entry permit is to insure that rescue efforts will be started promptly in the event a party is overdue.

RECOMMENDATIONS FOR ADDITIONAL INVESTIGATIONS

As a result of the present investigations, several issues have been discovered which warrant further investigation. These are numbered and briefly discussed below. We suggest that these investigations be conducted within the next year.

1. Groundwater tracing should be conducted to determine if waters from Taylor Camp Creek contribute to the flooding of La Caverna de los Tres Charros. This information would be very important in the event that people were trapped in the cave by flooding, and efforts were being made to divert water away from the cave.

2. Staff gages should be installed on both Dry Medicine Lodge Creek and on Taylor Camp Creek. They should be as near the entrance to Tres Charros as possible, but should be located so as to utilize effective natural channel control points. To aid in data interpretation, the valley cross section should be mapped at each staff gage site. In addition, a framework should be developed for correlating staff gage readings with flooding conditions noted in the cave.

The existing flood crest gage near the entrance to Tres Charros is in a location where it will not produce meaningful data. This gaging station should be abandoned, and replaced with the recommended staff gaging stations. The location and installation of good staff gage stations requires expertise in wildland hydrology to insure that resulting data will be as useful as possible.

3. Areas of the cave where people could escape floodwaters should be depicted on maps. We believe our existing map would provide an adequate base map for this work. The depiction of areas where people could escape floodwaters might differentiate between highly desirable and less desirable areas. Copies of these maps could be given to cave visitors. They would also be of great value in the event of a rescue.

The identification of suitable sites would require hydrologic expertise. In some places, it might be beneficial to leave some sort of simple device which would determine whether or not flooding of this area ever occurred.

4. Recommendations should be developed for additional survival cache locations in the cave. In addition, recommendations should be developed for contents to be included in the caches. This work would be closely tied to item 3 above.

5. A rescue plan should be developed for the cave. We believe that an adequate plan would require input from someone familiar with the cave and the potential flooding and rescue problems, plus input from BLM personell familiar with construction by heavy equipment and fire mobilization. We envision neither an elaborate nor highly detailed plan. Instead, we recommend a rescue plan designed to help land managers respond quickly and effectively to a rescue situation in the cave. The rescue plan would insure an orderly progression of rescue steps, and would help eliminate efforts which were unlikely to be beneficial to people injured or trapped in the cave.

REFERENCES

Aley, Tom and Cathy Aley. 1979. Cave assessment, monitoring, and management recommendations for Spirit Mountain Caverns, Bureau of Land Management, Worland District, Wyoming. October, 1979. Contract report under contract WY910-CT9-008. 68p.

*Beck, Barry. 1979. The long wait underground. Nat'l. Speleological Soc. News, May, 1979. pp. 103-104.

Craigle, Eileen. 1976. Diseases associated with caves. Proc. Nat'l. Cave Mngt. Symp., Albuquerque, N.M., Oct., 1975. pp. 111-113.

*Guy, Lin. 1979. Is it worth it? Nat'l. Speleological Soc. News, May, 1979. p. 104

Hill, Chris; Wayne Sutherland, and Lee Tierney. 1976. Caves of Wyoming. Geol. Surv. of Wyo., Bull. 59. 229p.

Monsson, George N. 1974. Reconnaissance report on the La Caverna de los Tres Charros Cave system, Big Horn County, Wyoming, and its hydrology. Ms. rept. 11p. plus map.

**Safeco Insurance Co. 1973. Four lines of defense against hypothermia. 2p.

**Stein, Jeremy M. 1976. Hypothermia. Proc. Nat'l Cave Mngt. Symp., Albuquerque, N.M., Oct. 1975. pp. 114-116.

U.S. Weather Bureau. 1961. Rainfall freauency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years. Tech. Paper No. 40. 61p.

* Included in Appendix A of this report.

** Included in Appendix D of this report.

APPENDIX A

Articles on cave explorers trapped underground by floods.

The Long Wait Underground

By Barry Beck
NSS 11737F

[By now you've all read about the great cave rescue in northwest Georgia. The media generally got most of the details right, eventually, although they were unnecessarily dramatic from the start. Let me take a few paragraphs here to set down some rudimentary details, make some personal comments, and express thanks for the whole group.]

ANDERSON SPRING CAVE is a large, effluent river cave on the west flank of Pigeon Mountain near Lafayette, Ga. It is on the order of 7,000 feet long, being basically one long river passage with an upper level at various places. Near the entrance the ceiling is low and one normally has to crawl on hands and knees in the stream with about a foot of air space for some 50 feet. Beyond that passage dimensions vary from roughly 15 feet square, up to canyon areas 75 to 100 feet high and 35 to 50 feet wide. About 2,000 feet into the cave one finds the first breakdown slope leading to a nicely decorated upper level which obviously never floods. The stream is perennial and varies from ankle deep to chest deep, under normal circumstances. Some 5,000 feet into the cave the main stream is blocked by breakdown and one has to wiggle and crawl for several hundred feet to find the way on. Beyond this the passage again opens up to large canyon dimensions.

On Saturday morning, March 3, I visited the cave with a group of students from the Outdoor Club at Georgia Southwestern College and my 13-year-old son Erik, a nine-year veteran of caving.

When we entered the cave it was drizzling lightly and had been all night. The stream was up a bit, but not seriously. I talked with Lawton Masengill, the manager of the Wildlife Management area on which the cave is located, and discussed the weather. He specifically asked what I would do if the cave flooded and I explained about the upper level and told him then that we would simply retreat to this area and keep warm and wait for any flood waters to recede. However, from the normal flow and the conditions when we entered, I didn't expect that the cave would siphon, even if the rain picked up to normal thunderstorm level.

We entered the cave at about 11:30 a.m. All the students were well-equpped with hard hats, spare lights, warm clothes and a durable lunch, as we had discussed previously. At about 3 or 3:30 we were near the end of the first 5,000 feet of large passage. The water did not appear to be rising significantly. We ate lunch and I gave the others the choice of continuing or exiting. Tony Johnson, who was having trouble with his carbide light, and my son Erik, who was cold, left. The other nine of us headed upstream. After exploring the breakdown for an hour or more we couldn't find the correct way through and decided to call it a day.

On the way back toward the entrance I noticed definitely increased inflow from small fissures in the ceiling. Former drips were now gushing water like a fire hose. In the large passage the stream did not appear to have risen much, but I knew it would in the constricted entrance and I urged the students to hurry. When we reached the low area, it was a near siphon. Since several of the students were inexperienced as cavers I decided not to push it. Mark McKoy and Tony Able, both very level-headed and responsible students whom I knew well and trusted, asked if they might try it. I said they could look it over and try if they judged it feasible, but definitely not to do any long submerged sections. "If you're not back in 10 minutes we'll assume you left and take another look at it," I said. When they didn't return we did evaluate the exit route, but found it too close to be safe for our group, now cold and somewhat apprehensive.

We retreated back upstream and climbed the breakdown to an upper level. We were all wet to the neck. Our party now numbered seven: myself and Cheryl Gillis, Mary Faye Smith, Warren Moore, Dennis Hudgins, Louis Pounds and Steen Madsen, a Danish exchange student. Realizing that we must keep warm we found a sheltered crack between a large block and the wall and laid down in a pile, wrapping ourselves around each other as much as possible. This was probably our worst moment as everyone was still cold and wet. The pile never lasted long because the upper people would get cold and the lower people would get squashed.

Every hour or so we'd get up and walk around and exercise a bit. Sometimes we'd walk down to the river to check the level.

After eight to 10 hours we began to notice that we were drying off. From then on we had no problems. Every couple of hours we would gather around our supplies and share a snack. We made a pot of soup; boned chicken in a can of water heated over a candle — not tasty, but hot and this was important. In fact, I would recommend a candle for just this purpose: not light, heat.

Finally, the river dropped to the necessary low and we suited up to exit. As we were standing on the bank checking lights and gear we heard voices from the river, then we saw lights: two scuba divers coming to rescue us. We greeted them joyously and they told us about the giant, three-ring circus await-

Beck and students wait it out.

©Louis Pounds

ing us outside. Our exit was uneventful. The divers helped us through the low spot with an aqualung, but there was four inches of air space and it really wasn't essential.

Outside we were whisked into blankets and wrapped and administered to. The students were bundled off to the hospital for a check-up, although I asked to be allowed to change first since my van was still right there. After a couple of hamburgers and a few relaxing cool ones, I drove up to the hospital for a routine check-up. Final result: everyone was totally unscathed and ready to go caving again.

Outside, I understand, it was different. The media would not listen to those who insisted we knew what we were doing and created unnecessary trauma, especially for parents and relatives. Certainly there was serious danger, but it could have been minimized, not dramatized. The Walker County Cave Rescue Squad (made up largely of cavers but assigned to the county civil defense unit) responded efficiently. From inside the cave, it was a great comfort to know that Smokey Caldwell, Allen Padgett, Steve Hudson and the rest of the trained rescue squad from Dogwood City Grotto would be waiting if we needed them. A special hypothermia team from Virginia was flown in by the Air Force; their efforts were coordinated by the National Cave Rescue Commission via Dan Smith in California. Local agencies helped immensely. The Walker County Sheriff's Office, Civil Defense and Red Cross all worked around the clock and contributed their resources and personnel efforts freely. John Tench Restaurant and Restaurant Enterprises, and even local neighbors, contributed food. State Police kept the roads open and attempted to control the crowds, and the Emergency Health Service ambulance stood by in the event it was needed. Joe Tanner, director of the Georgia Department of Natural Resources, and various members of his staff were on site throughout the two days. Lawton Masengill, area manager for the DNR, lives very close to the cave and he and his wife opened their house and played host to countless visitors throughout the rescue. After our exit from the cave we were taken to Tri-County Hospital in Fort Oglethorpe, Ga., for a routine check up. Although we may not have appeared properly grateful at the time, all of us who were in the cave do greatly appreciate all the efforts that were expended in our behalf and the concern which so many people showed for us.

In retrospect I'd like to make a few editorial comments. After the rescue there was some criticism of me in the media from other cavers. I don't mind the criticism, too much; everyone is entitled to his own opinion. However, I don't think two responsible NSS members need to air dirty linen in the national media.

The decision to enter in the rain was mine alone. In normal heavy rain I felt we wouldn't have a serious problem. The fact of the matter is that it rained eight inches, according to the Chattanooga paper, that afternoon. According to the National Weather Bureau statistics, such a rain will occur in that area only once every 15 years. Life can only be analyzed backwards, but it must be lived forwards.

Inside the cave, it was a team effort. It was not a student-professor relationship. It was seven people working together for the good of all. We knew what to do and we did it. There was never any doubt as to our safety; no hysteria, no bickering. We were in control of the situation at all times and we did exactly what I had told Ranger Masengill we would do in this event.

This does not mean that we don't appreciate the efforts of those outside. Many of them suffered great inconvenience, discomfort and even risked their lives to aid us. Their presence could have meant the difference between life and death. It is great to know the system works, and even greater to know you have friends like these. In closing, I would like personally to apologize to cavers in general for all the fuss and publicity. I sincerely hope it is not detrimental to the Society and caving.

Is It Worth It?

By Lin Guy
NSS 10235

ON JULY 14, 1973, two of us emerged prematurely from a low, wet cave on Lookout Mountain in Georgia, suffering from the very earliest stages of hypothermia. Although it was clear when we entered, the ground outside was wet, and a store owner told us it had rained so hard "you couldn't see 50 feet." I reflected on how lucky we were the water in the cave hadn't risen a few inches while we were inside, and was glad to see the rest of the crew emerge from the half-mile-long cave. Several places inside were little more than a foot high with two or three inches of airspace.

During the fall of the next year I changed plans at the last minute to help explore a multiple-drop wet cave in Alabama after the Friday weather report gave over 50 per cent chance of rain. During July 1975, in the same cave, a crew of 10 cavers was halted below the eighth drop by rising water. After a four-hour wait the group decided to exit, during which they were battered around under tremendous waterfalls, and the coldest-natured persons suffered the onset of hypothermia. What was once a "dangerous" or "foolish" undertaking was now acquiring a new label: "sporting." With Mother Nature no longer a "problem," many southeastern cavers no longer felt it necessary to pay any attention to the weather. I was told by one (who holds the NSS's highest award) that caves in TAG country are different than those in Indiana, where several persons had just drowned in a flash flood. "Besides, you can always reach high ground and wait for the water to recede."

Well, this is a grand philosophy if you and your friends are the only folks on earth. But while you're waiting, if you have a spouse, or perhaps parents, at home, they are going to be worried to death. They are also going to be calling the rescue squads out to find you, which usually generates the type of publicity which is **always** detrimental to our hobby. You may know you are safe. Your friends may be fairly confident you will make it out alive. But the "outside" world doesn't understand these things.

While seven explorers were making national headlines while trapped inside a Georgia cave on March 4, 1979, another group was similarly delayed in exiting a cave 25 miles away in Tennessee. The group entered the cave on Saturday morning and got out a day later than planned, on Sunday evening. (Vehicles driven up to the entrance had to stay in the cove even longer due to high water.) A worried parent called the sheriff just before word was received that the group was out safely. Fortunately, the sheriff was stopped before a full scale rescue operation was implemented.

It isn't time to end exploration because the hazards of getting to "the bitter end" have increased. It's just time to minimize the hazards. Closer attention should be paid to last minute weather reports, and if a trip has to be postponed because water may rise in the cave, at least you will have avoided the possibility of a lot of bad publicity to our hobby. And you will probably live to see another weekend to push on to "the bitter end."

APPENDIX B

Detailed discussion of histoplasmosis from the Spirit Mountain Caverns report.

Histoplasmosis and other lung diseases: Histoplasmosis is a lung disease associated with inhaling spores of the fungus Histoplasma capsulatum. Although infection is common (Criagle, 1976), there is generally either no detectable illness or only mild respiratory symptoms. However, there is a progressive type of the disease which is often fatal; this most commonly involves an intense exposure to the spores of Histoplasma capsulatum.

Histoplasmosis is endemic in certain areas of the United States, and in some tropical regions as well. Positive histoplasmin skin tests indicate that 80% of the population in the Mississippi-Missouri-Ohio River Valleys have been affected (Craigle, 1976). In contrast, Histoplasma capsulatum has to date been reported at only one site in Wyoming. The site is Spirit Mountain Caverns.

The Center for Disease Control in Atlanta, Georgia made the determination that Histoplasma capsulatum was present in a sample sent to them. The nature of the sample, as described by Lydy (1979) in a letter to the Cody BLM office, was "composed of dirt, feathers, rat pellets, and a variety of unidentified material; really nasty looking stuff". The sample was collected by two BLM cave rangers. Although no information on the precise location from which the sample was collected was found in the BLM files, the presence of feathers in the sample indicates that it was collected either in the Pigeon Roost area or on the route to that area. This was confirmed by Pete Uhl, one of the BLM cave rangers who collected the sample.

Spores of Histoplasma capsulatum have been found only in association with bird droppings and bat guano. Based upon a discussion in 1979 with Dr. Robert W. Lichtwardt, a mycologist at the University of Kansas involved in study of this fungus, spores of Histoplasma capsulatum have never been found associated with droppings from packrats. The explanation for this may be related to differences in the digestive systems and digestive enzymes between bats and birds and other vertebrate animals.

Regardless of the explanation, the restriction of spores of Histoplasma capsulatum to bird droppings and bat guano has cave management significance in Wyoming. Our concern about histoplasmosis can be restricted to areas of caves which contain bat guano or bird droppings.

We saw no bats in Spirit Mountain Caverns; cave dwelling bats are generally rare in Wyoming caves. Packrat droppings are scattered throughout the cave. Large bird populations are uncommonly associated with caves, but Spirit Mountain Caverns, with its large pigeon population, is a notable exception. Pigeon use of the cave is restricted to the Pigeon Roost area, although some of the pigeon droppings and feathers have migrated into some of the small passages on the route between the main level of the cave and the Pigeon Roost area. Packrats have probably helped spread this material around.

During our field work we collected nine samples of soil and fecal material from Spirit Mountain Caverns for subsequent analysis for the presence of spores of Histoplasma capsulatum. The samples were collected in sterile bags using sterile spoons. The samples were given to Mr. Wayne Holm at the BLM office in Cody; he will ship them to the Center for Disease Control in Atlanta, Georgia where analysis work will be done.

Table 1 summarizes data on the location of the nine soil and fecal sample collection sites in Spirit Mountain Caverns; the locations are shown on the map in Figure 17. Table 1 also indicates whether the collection site was a location where cavers were likely to travel and thus be exposed. Some of the samples were collected from packrat debris in small alcoves where people would not travel.

The analysis of samples for Histoplasma capsulatum (as conducted by the Center for Disease Control) takes several weeks. As a result, we have not yet received the results. Once the results are received, we will analyze them in an addendum for any impacts they may have on cave management. BLM personnel will add this addendum (Addendum 1) to all of their copies of the report. However, based upon our present knowledge of the natural history of this fungus and the nature of the cave, we believe we can develop prudent management recommendations for relating to this hazard without waiting for the final results from CDC. Any changes in our conclusions and recommendations will be incorporated in Addendum 1.

Although histoplasmosis is a newly discovered issue affecting cave management in Wyoming, it is not a new issue in other parts of the United States. Management approaches used by other state and federal agencies in areas where histoplasmosis commonly occurs can give some guidance to BLM in dealing with the issue in Wyoming.

The BLM files in Cody contain some very helpful correspondence between Thomas Enright and Warren C. Lewis, M.D. on the subject of histoplasmosis (Appendix B)*. Dr. Lewis states that Histoplasma capsulatum spores have been found in several caves open to the public, including Carlsbad Caverns in New Mexico (administered by the National Park Service). Spores of Histoplasma capsulatum could probably be isolated from Mammoth Cave, Kentucky (administered by the National Park Service), Blanchard Springs Caverns in Arkansas (administered by the U.S. Forest Service), as well as many other public and private caves. At these caves, visitors are not warned of any special hazards. Employees or visitors working or exploring where they could stir up spores are typically cautioned about the disease. We believe this to be a proper course of action.

As mentioned earlier, the severity of the disease tends to be associated with the intensity of the exposure. Fatal cases of histoplasmosis have resulted in Missouri among workmen who were bulldozing out trees and leveling the ground in areas which supported giant starling roosts; nearby residents were not affected. With cavers, cases of histoplasmosis serious enough to involve medical treatment have typically resulted from horseplay in piles of bat guano and/or nearby cave dirt. In addition, a number of cavers who have visited caves in central America or the Caribbean have also suffered bouts with histoplasmosis. Many of these tropical caves contain hundreds of thousands and even millions of bats; cave

* Found only in the Spirit Mountain Caverns report.

Table 1

Location and related data on soil and fecal samples collected in Spirit Mountain Caverns for *Histoplasma capsulatum* analysis.

Sample #	Cave Level	Location	Caver Exposure Likely?
W-1	1	Top of Credibility Gap; packrat debris.	No
W-2	1	Top of Credibility Gap; typical cave dirt	Yes
W-3	between 2 & 3	Guano Room Bypass route; crawl immediately above Guano Room Pit. Typical cave dirt.	Yes
W-4	3	Lower end of main linear passage.	Possibly
W-5	4	Main route in lowest level of the cave; typical cave dirt.	Yes
W-6	2 on route to 1	Halfway between main passage and Pigeon Roost Area. Vicinity of previous positive histo sample. Cave dirt, packrat droppings pigeon feathers and droppings.	Yes
W-7	2	Packrat debris in alcove along the main passage 80 feet from gate.	No
W-8	2	Main passage at the intersection with the route to the Pigeon Roost area. Typical cave dirt.	Yes
W-9		This sample collected at Horsethief Cave	
W-10	between 2 & 3	Guano Room Bypass route; breakdown chamber above Guano Room Pit. Typical cave dirt.	Yes

exploration involves substantial contact with bat guano. Prudent cavers who have a concern for the well-being of their lungs do not romp through the guano nor frolic in dust contaminated with bat or bird feces.

Based upon our understanding of histoplasmosis, the risk of potentially contacting a detectable case of this disease is negligable in most portions of Spirit Mountain Caverns. The hazard exists only where there is a substrate of pigeon droppings; these conditions are found only in the Pigeon Roost area and in immediately adjacent areas.

People traveling toward the Pigeon Roost area from level 2 of the cave must pass through some steeply inclined crawlways where it is impossible not to stir up dust. As one nears the Pigeon Roost area, this dust becomes obviously contaminated with pigeon droppings and feathers. In order to make it all the way to the Pigeon Roost area, it is now necessary to partially excavate a connecting crawlway; the crawl is primarily plugged with pigeon droppings. The fact that we did not excavate this passage and continue on to the Pigeon Roost area is indicative of the seriousness with which we view this hazard. Similarly, we did not descend into the Pigeon Roost area from outside the cave; we did not view this as prudent either.

Histoplasmosis is not the only disease which can be associated with bird droppings. Several years ago one of the authors of this report had a serious case of parrot fever and pneumonia which lasted for several weeks. This was a result of cleaning out a Missouri turkey house which had been unused for several years. Possibly this or similar diseases could result from travel into those portions of Spirit Mountain Caverns which are heavily used by the pigeons.

Management recommendations on histoplasmosis: With respect to the hazards of histoplasmosis and other bird-related diseases, the following cave management actions are recommended.

1. The risk to visitors does not warrant the closure of the cave or general restriction of access. Many people have visited the cave in the last few years, yet to our knowledge there have been no reports of cases of histoplasmosis which might have been related to visitation of this cave.

2. All visitors to the cave should be cautioned that the fungus Histoplasma capsulatum has been isolated from a sample containing pigeon feathers and feces, packrat droppings, and cave dust. Although the pigeon feces are almost certainly the only medium which will support the spores of this fungus, it is prudent not to stir up any dirt or fecal material found in the cave. An adequate gate and a permit system for the cave would insure that all visitors were cautioned about this hazard.

3. Visitors should be warned that the Pigeon Roost area and the route to this area are considered to be hazardous because of the fungus Histoplasma capsulatum and the abundance of pigeon feces, which provide a good substrate for this fungus.

4. A sign should be placed on the route to the Pigeon Roost area informing visitors that this is the area of the cave where the hazard of histoplasmosis is believed to be significant. The sign should be placed at the entrance to the first crawlway after leaving the main cave passage on the route to the Pigeon Roost area. The sign should strongly recommend that people not proceed further. The sign might also state that the passages beyond are small and not of particular interest.

5. Spores of the fungus Histoplasma capsulatum can persist in soils for many years. Exclusion of pigeons from the cave would not solve the problem. Soil sterilants do not effectively kill spores of Histoplasma capsulatum. Histoplasmosis is a long term and uncorrectable situation which will always require at least some management attention.

APPENDIX C

Discussion of Cave Radiation

All caves contain some natural alpha radiation. The caves administered by the Bureau of Land Management are no exception. The purpose of this discussion is to give land managers an understanding of the issue, an assessment of the significance of the possible health hazard, and our recommendations for dealing with the issue.

General cave radiation information is included in this appendix so that it will not need to be repeated in three separate reports. Data on cave radiation which is specific to a particular cave is found in the text discussions about that cave; the reader should consult this material.

The cave radiation issue: Most people do not realize that there are varying levels of natural alpha radiation everywhere. Detectable concentrations can be measured out in the open air, in buildings, and in all caves. Natural alpha radiation occurs because there are small amounts of uranium and thorium in all rocks and soils. During the atomic decomposition of these materials, alpha radiation is produced.

Since alpha radiation is derived from materials in soil and rock, buildings made of earth and rock materials tend to have higher alpha radiation concentrations than buildings made of materials such as wood. Because they have less air exchange and more contact with soil and rock, basements and energy-efficient underground buildings typically have higher alpha radiation concentrations than above-ground buildings.

Alpha radiation can also be measured in caves, since caves are surrounded by rock and soil. Since natural radioactive materials are not distributed uniformly in soils and rock, and since air circulation patterns are not uniform in caves, alpha radiation concentrations may vary from point to point in cave systems.

Very high alpha radiation concentrations can be found in portions of uranium mines which are poorly ventilated. Medical studies of miners have indicated that exposure to alpha radiation increases the liklihood of eventually developing lung cancer. The greater the contact with alpha radiation, the greater is the possibility of eventually (perhaps in 20 or 30 years or so) developing lung cancer.

An obvious question is, why should alpha radiation increase the liklihood of lung cancer? Alpha radiation is a low energy ionizing radiation which can damage extremely delicate cells. Lung cells are extremely delicate, and they do appear to be damaged by alpha radiation. Although we do not know what causes lung cancer, it does appear that damage to lung cells (whether from alpha radiation, cigarette smoke, air pollution, or a host of other things) increases the liklihood of lung cancer.

There has been no research done to determine safe limits for exposure to natural alpha radiation. As we consider alpha radiation, it is important that we recognize it as a form of radiation which we cannot totally escape.

It is estimated that about 80% of lung cancers in the U.S. are related to cigarette smoking. Other lung cancers are related to asbestos and other carcinogens. Natural alpha radiation is well down the list of hazard factors.

Studies were conducted by the National Institute for Occupational Safety and Health on employees at National Park Service caves open to the public (these include Mammoth Cave, Carlsbad Caverns, and about half a dozen others). These studies did not show any correlation between employment in caves and increased occurrences of lung cancer. Since in medical research it is almost impossible to show that something is safe, these tests did not show that periods of cave work might not increase the liklihood of lung cancer by some small amount.

Aside from the research mentioned above, most of our insight into possible alpha radiation health problems comes from medical studies of miners. There are several reasons why alpha radiation as encountered in caves may be less hazardous than that encountered in mines. For example, mine air is contaminated by diesel smoke and dust, both of which are harmful to the lungs. In contrast, cave air is typically cleaner.

Significance of the human health risk: Although alpha radiation as encountered in caves may not be as harmful as alpha radiation as encountered in mines, it seems prudent to presume that it is. Based upon this presumption, we can use some of the rule of thumb values relating alpha radiation exposure in mines to the increased liklihood of lung cancer, and develop some numbers which will help place the cave radiation issue in perspective.

Let us assume that a "typical caver" takes five caving trips to BLM administered caves in a year. Let us further assume that two trips are to Horsethief Cave (where he spends a total of 20 hours), one trip is to Spirit Mountain Caverns (where he spends a total of 5 hours), and the last two trips are to La Caverna de Tres Charros (where he spends a total of 10 hours). This represents a total of 35 hours underground. Based upon mean alpha radiation concentrations measured at these caves, he would receive a total of 0.153 working level months of natural alpha radiation; his mean exposure rate would be 0.75 working levels per hour.

During the year that our "typical caver" does the caving outlined above, he will receive about 15% of his total alpha radiation exposure from BLM caves. The remaining 85% of his exposure comes from other environmental exposure; most of it is from living and working in buildings.

At age 30, our "typical caver" would have received only about one half of one percent of his total alpha radiation from his year of exploring BLM administered caves. The majority of his exposure would have been from buildings.

If we had 100 active cavers each year, and each of them followed the schedule of our "typical caver" and experienced similar radiation exposure from BLM caves, we should anticipate one excess lung cancer among this group every 875 years. Of course, this cancer might be curable. Based upon our "typical caver", we should anticipate one excess lung cancer for every 2.3 million man hours of caving in the three caves involved in our study.

If our "typical caver" lives in Laramie, his five cave trips in a year will represent about 3,500 miles of highway travel. Based upon national highway fatality statistics, there are approximately 3.4 fatalities in the United States for every 100 million miles driven. As low as this value is, the chance that the caver will be killed in a traffic accident on a cave trip is about 8 times greater than the probability that he will ultimately suffer a lung cancer from his year of caving in BLM caves. On a per hour basis, the chance of our "typical caver"

ultimately getting a lung cancer from exposure to cave air in BLM caves is about equal to the risk of being killed in the crash of a commercial Boeing 737 on a domestic flight. The Boeing 737 is the safest U.S. commercial airliner; this plane has experienced only 0.04 fatalities for every 100,000 hours of passenger flight time.

Among federal land management agencies, the National Park Service has been a leader in warning the public about hazards. The NPS (with the concurrence of the Environmental Protection Agency) does not view the cave radiation hazard as sufficient to justify warning of visitors at any NPS cave open to the public. During the course of a year, visitors to either Carlsbad or Mammoth receive a total alpha radiation exposure 400 times greater than that received from BLM caves by 100 active cavers following the schedule of our "typical caver". Medical research indicates that it is the total dose and not the rate of exposure which is important; for this reason the comparison of exposures between NPS and BLM caves is appropriate. Private show-caves and the National Park Service do inform employees about cave radiation; this is required under the precautionary cave radiation standards presently in force.

In an era where the word "cancer" carries panic connotations it is easy to react too strongly to a "newly discovered" potential hazard. It is our view that this is precisely what has happened with the cave radiation issue. As a result of overly reactive fears that caused a "caving causes cancer" campaign, cave management and cave safety efforts have been diverted away from things which are crucial, and have been concentrated on a risk which is minor in significance.

In Horsethief Cave, the cave radiation hazard can be compared quantitatively with the hazard of becoming so seriously lost that rescue is necessary. This comparison will further help to put the cave radiation hazard in perspective as a minor (and not a major) hazard.

The extensive portions of Horsethief Cave were discovered in 1970 (Sutherland, 1971). Within less than a year, one person was lost in the cave for 36 hours, and had to be rescued by cavers (Sutherland, 1971). In the BLM files in Cody we noted that a party of two people also became lost and required rescue a few years ago. Becoming lost and/or losing one's lights is a major hazard in Horsethief Cave.

Based upon data in the Cave Management Plan (BLM, 1978) visitation in Horsethief Cave is now limited to 400 people per year; this limit was based upon past usage. If we assume that the average trip in this cave lasts 10 hours, and that there have been 400 people per year visit this cave in the nine years since its discovery, then this represents a total of about 36,000 hours of cave use. Since at least three people have become lost and required rescue during this time, one person becomes lost for about every 12,000 hours of caving time. If we compare this value to the radiation hazard experienced by the "typical caver" spending 35 hours a year in three BLM administered caves, we derive a very interesting value. The risk of becoming lost in Horsethief Cave and requiring rescue is about 200 times greater than the risk that someone will ultimately experience lung cancer as a result of exposure to alpha radiation in BLM caves. To date, there have been no significant injuries or fatalities among those lost in Horsethief Cave; the people have been lucky. It certainly does not indicate that being lost is a harmless event.

Concern about cave radiation has diverted management attention away from more significant safety issues. This is clearly illustrated

by the above example. There are many other cave safety and cave management issues which are far more important and crucial than the cave radiation issue.

Finally, warnings to visitors should reflect a priority ranking which is related to risk. To do otherwise may result in visitors concentrating on trivial risks while paying less attention to major hazards. Furthermore, failure to adequately assess the magnitude of risks damages the credibility of the person and the agency giving the warnings; this can result in the visitor largely ignoring all warnings.

Management recommendations for dealing with the cave radiation issue: This appendix includes, as Attachment 1, the precautionary cave radiation health standards adopted by the National Caves Association. These are the standards which are currently in force for show-caves (commercial caves). There are no state or federal standards which apply to human exposure to alpha radiation encountered in caves. It is the policy of the federal Occupational Health and Safety Administration (OSHA) that federal operations shall be governed by health and safety standards no less stringent than those in force in the private sector. For this reason, the precautionary cave radiation standards which are enclosed are national standards and apply to federal agencies.

The precautionary cave radiation health standards (Attachment 1) are designed for show-caves which are open to the public. They are not specifically designed to cover undeveloped or "wild" caves such as those administered by BLM in Wyoming. However, the precautionary standards for show caves do provide extremely helpful guidance for managers of undeveloped caves. Our recommendations for dealing with the cave radiation issue rely heavily on the existing precautionary cave radiation health standards, and are compatable with them.

Our specific management recommendations are as follows:

1. Alpha radiation should not be considered as a major health and safety issue in cave management.
2. Based upon alpha radiation concentrations measured in Spirit Mountain Caverns and the fact that most visitation will be of short duration, we do not believe it is necessary for BLM to caution visitors to this cave about cave radiation. We estimate that the average visitor will spend about two hours in this cave. Based upon our measurements, the total amount of alpha radiation he will receive from this cave is approximately equal to that he would receive from spending four days in a building.
3. Based upon the low alpha radiation concentrations measured in La Caverna de Tres Charros, we do not believe it is necessary for BLM to caution visitors to this cave about cave radiation.
4. In view of the existing precautionary cave radiation standards and decisions by other federal agencies that visitors need not be warned about cave radiation at caves like Mammoth and Carlsbad, we do not believe it is necessary for BLM to caution visitors to Horsethief Cave about cave radiation.
5. Because visitors often spend long periods of time in Horsethief Cave, BLM might wish to bring the cave radiation issue to the attention of visitors to this cave. A possible wording for handout material for Horsethief Cave is in the health and safety considerations section of the Horsethief Cave report.

6. With respect to employees doing cave work, BLM should comply with the provisions of the precautionary cave radiation standards (Appendix 3, Attachment 1).

Attachment 1, Appendix C

NATIONAL CAVES ASSOCIATION

Precautionary Cave Radiation Health Standards for Natural Caves Developed for Visitation by the General Public. Adopted April, 1978; Ratified November, 1978.

1. Where radiation monitoring is not done, underground work shall not exceed 700 hours per year for any employee.

2. Where radiation monitoring is done, annual cumulative radiation exposure shall not exceed 4.0 working level months of alpha radiation exposure for any employee.

A. Where monitoring is done, and adequate data have shown a seasonal repeatability in radiation concentration levels, professional scientific judgement shall be exercised as to the frequency of subsequent monitoring.

B. For monitored caves where the data base does not show a reasonable predictability in radiation concentration levels for the period being sampled, the following monitoring frequency will be used for monitoring occupied areas during those times when they are being regularly visited by employees:

0 to 0.10 working levels: Annual measurement during that season when underground work time is greatest.
0.11 to 0.20 working levels: Semi-annual sampling.
0.21 to 0.30 working levels: Quarterly sampling
Over 0.30 working levels: Weekly sampling and record keeping on employee exposure accumulations.

Note: The working level range is based upon the average of the values obtained in a single sample set. The maximum average value on record should be used unless collected data suggest that this set is atypical. This table should be used flexibly by cave managers as a "sliding" scale linked with seasonal cave radiation variations.

3. Smoking in caves, either by employees or visitors, is prohibited.

4. Except as provided below, cave air shall not be used to ventilate buildings used by employees or visitors, nor shall cave air be allowed to freely enter such buildings:

Exception 1: Buildings which are used exclusively for entry to or exit from a cave are excepted.
Exception 2: Buildings where no individual employee spends an average of more than 5 hours per week are excepted.
Exception 3: Buildings where radiation monitoring indicates that average alpha radiation levels are less than 0.10 working level are excepted. This applies regardless of whether radiation control measures are utilized in the building or not.
Exception 4: Buildings where radiation monitoring indicates that average alpha radiation levels are less than 0.30 working level are excepted if cave air was used for ventilation of this building during the summer of 1977.

5. The potential health hazard of alpha radiation in caves must be explained to all permanent employees who will be doing any underground work before they begin their employment.

APPENDIX D

Articles on the hazards of hypothermia

Hypothermia

Jeremy M. Stein*

Death by exposure, freezing to death, hypothermia—all are the same thing. They mean a lowering of the temperature of the inner core of the body; if this temperature is lowered far enough, death follows.

Who is in danger from hypothermia? Anyone who spends much time outdoors is a possible victim. This means hikers and campers, skiers and snowshoers, hunters and fishermen, victims of crash or breakdown, sailors and swimmers, and, of course, climbers and cavers. I suppose some of you reading this will say that cavers have no need to fear hypothermia. but you are wrong. There are recorded deaths due to hypothermia among cavers and hypothermia has been a contributing factor in many accidents; these victims may also have thought they were in no danger from it.

Why is a low body temperature such a serious thing, and how can it cause death? That's not an easy thing to explain, but let's try. Your body is a heat engine, burning food in order to produce the heat needed for all body processes to go on. The process of heat production becomes less efficient when the body core temperature falls below the optimum level of about 99° F. If the temperature falls very much below this level, all body processes begin to slow down. If they slow down too much the body can no longer produce enough heat to raise the body temperature back to its proper level. The heat producing processes slow down still further, even if further loss of heat is prevented, and the eventual result is death.

Let's look at the way your body responds to cold. The first response is to constrict the outermost blood vessels, and then those just under the skin. This constriction reduces the amount of heat transported to the outer layers of the body and therefore reduces the amount of heat lost there. This constriction also reduces the skin temperature, and thereby provides a cooler layer of tissue to act as insulation between the body core and the cold environment. The skin temperature may fall to nearly that of the outside, while the core temperature remains at 99° F. A fall in skin temperature to 50° has the effect of reducing skin sensitivity and pain responses, and also lowering the strength of the muscles located near the surface. This loss is especially apparent in the muscles of the hand. These changes render the hands nearly useless in the performance of any critical or delicate maneuvers. Shivering also starts soon after the constriction of the surface blood vessels takes place. This shivering is a very effective method of heat production, but it is extremely strenuous exercise and may exhaust the victim in a very short time, especially if he is tired already or not in good physical condition. If the exposure to cold continues after the constriction of the surface blood vessels, the body core temperature begins to drop. It is this fall of core temperature which is called hypothermia.

How does the body lose heat? There are basically five ways: radiation, conduction, convection, evaporation, and respiration.

Radiation is the primary mechanism of heat loss in most situations. Most of this heat is radiated from the head, which is heavily supplied with blood and is usually exposed. At 40° F. half of the body's heat production may be lost from the uncovered head; at 5° F. up to three-quarters of the body's entire heat production may be lost from the head alone. Thus the saying, *If your feet are cold, put on your hat*. For this reason, a hat is one of the most important defenses to have against hypothermia.

Conduction is not normally a large mechanism of heat loss. For cavers, however, who are frequently in contact with considerable areas of cold rock, it is probably appreciably greater than for most people. The rock may be only as cold as 50 or 60° F., but this is so much colder than the body that considerable heat may be lost by conduction if little insulation is present between the body and the rock.

Convection is small in still air; however, when there is any appreciable wind, the losses due to convection rise abruptly. Thus we see the wind-chill charts, which show that the chilling effect of any given temperature is doubled by a wind of only three miles per hour. Clearly, the effects of wind must be considered when dressing for the weather. Most caves have a moderate breeze blowing in them at all times; this breeze may become quite a bit stronger in some areas within the cave. One of the very best items to carry for protection against hypothermia is some kind of tightly woven windproof outer garment, such as a windshirt.

Evaporation is the next cause of heat loss to be considered. If you become wet, much of your body heat production will be used to evaporate water, which process will cool you down considerably. In addition, the water will conduct the heat much more rapidly to the outside environment. We all know how cold it feels to step out of a swimming pool, especially if there is any wind blowing; we feel cold even if the air temperature is 90° F. or more. Imagine how much colder you would feel if the air temperature were 50° F. or less! The best protection from heat losses by evaporation is simply not to get wet; whether from runoff, ground water, or perspiration. If you do get wet, you should have emergency dry clothes available to you. In some cases, it is better to take off your clothing, let your body get wet, and then put your dry clothes back on; you will warm up quickly, and your clothes will warm you much better than if they were wet.

Finally, the last mechanism of heat loss is respiration, which is the heat you expend in warming the cold air that you breathe in. In addition, heat is lost in the process of evaporating water in the lungs into this inhaled air. Both the heat and the moisture are lost to you when you exhale. Little can be done to reduce this mode of heat loss, although if the weather is cold enough, tunnel-shaped hoods can provide a significant reduction.

How can you tell if someone is suffering from hypothermia? Let's look at the symptoms which appear as the core temperature falls.

As the body temperature drops below 99° F., the first symptoms are violent shivering and a slight decrease of the ability to perform complex tasks. The next sign of chilling is an increasing difficulty in speaking. Sluggish thinking and some degree of amnesia may appear by the time the core temperature drops to 91° F. The shivering now decreases and is replaced by a considerable degree of muscular

* 4931 Kathryn Circle, SE, Albuquerque, NM 87108.
Copyright © 1976 by Jeremy M. Stein.

rigidity. Exposed skin is likely to become blue or puffy, and muscle coordination is affected. The victim appears clumsy; speech becomes blurred; thinking is less clear; but the victim still appears to be aware of his surroundings. As the core temperature drops below 85° F., the victim becomes irrational, pulse and respiration slow down, and the victim drifts into a stupor. The final phases of the cooling are unconsciousness, gradual failure of reflexes, and, usually below 78° F., death.

The above symptoms are not all always present, but the general course of events is usually followed. There is some evidence that the entire series may be hastened and abridged somewhat by lower than normal levels of blood sugar, and by exhaustion or poor physical condition.

Note that by the time the victim is in serious trouble, he is probably unable to do very much to rescue himself, and may not be aware of his danger at all. By the time many people realize they are in trouble, they have lost the ability to get out of their predicament. For example, the victim may by that time be too clumsy to build a fire.

A number of factors help make hypothermia more likely. The wrong clothing or insufficient clothing usually is a major factor. Poor physical condition or exhaustion frequently enters in. Getting wet and being exposed to drafts or breezes are almost invariably causes. If one were to select a typical victim, he would be lightly dressed, tired and wet from heavy exertion, resting for a while in a light or moderate breeze with his head uncovered. Victims under precisely these conditions, with the air temperature between 40 and 50° F., have died in less than two hours from the first noticeable symptoms. Note that in cases of shipwreck in the North Atlantic, where the water temperature was between 31 and 35° F., the survival time ranged from 15 to 30 minutes; this loss of heat was due almost entirely to conduction, and illustrates how little time you may have if you become thoroughly wet. It should be clear by now that knowledge of the symptoms and causes of hypothermia are important to cavers.

To repeat the symptoms:

Intense shivering
Loss of coordination
Difficulty in speaking
Clumsiness
Amnesia or unawareness of surroundings
Muscular rigidity
Irrationality
Hallucinations
Blueness or puffiness of skin
Dilation of pupils
Weak or irregular pulse
Stupor.

What is the first aid for victims of hypothermia? Basically, it is to provide heat to the victim and preserve the heat he has left. Note that it will do no good only to conserve the heat the victim has left; he is unable to survive if that is all that is done. There are a number of cases on record in which the victim was rescued, placed in a sleeping bag, and died while being carried out. The victim's body was unable to bring his temperature up again, so his temperature fell until he died.

How should heat be supplied to the victim? The needed heat may be supplied in any way that is feasible for the rescuers. The Mountain Rescue Council here in Albuquerque uses a vest made of two layers of cloth with a piece of plastic tubing going back and forth between them. This tubing has a hand pump at one end; in use, the victim is placed in the vest, then into a sleeping bag (for insulation), and then warm water is pumped through the vest continuously until the victim's temperature is back to normal. The vest uses about two cups of water, which is easily heated by a small camping stove. Similar devices, called hydraulic sarongs, hypothermia bags, etc., are in use in most areas where hypothermia victims are at all common. If this equipment is unavailable, heat may be supplied to the victim in many other ways. The best is to immerse him in a bathtub filled with water at 110° F.; such items are rather uncommon in caves. Chemical hot packs or hot water bottles may also be used, but great care must be taken with these not to burn the victim. Perhaps the best emergency measure is to place the undressed victim in a prewarmed sleeping bag with an undressed rescuer, who provides life-saving heat for the victim at the price of considerable personal discomfort. Even if the victim and the rescuer are of the opposite sex this can in no way be regarded as fun; indeed, it will probably be necessary to exceed the cold tolerance of more than one rescuer in order to rewarm the victim sufficiently.

In addition, if the victim is conscious, he is given warm liquids and sweets to eat. These can obviously not be used with an unconscious victim. Under no circumstances should the victim be given alcohol or any drinks containing alcohol. It opens the peripheral blood vessels, thereby removing still more heat from the core.

How can you prevent the occurrence of hypothermia? First and chiefly, be aware of the danger. Dress for the worst conditions you expect to encounter, and a little worse still. Avoid getting your clothes wet, and minimize your heat loss whenever possible. Do not use down clothing if there is any possibility of getting wet; down becomes useless when wet. Under these conditions, use Fiberfill II or Polarguard, which are nearly as good as down when dry, and very much better when wet. Clothing made of these materials has the additional advantage that it may be squeezed out and put back on if it becomes soaked. Foam clothing, such as a wet suit, is also useful under wet conditions. Provide yourself with a hat, preferably one that covers the head and neck completely, such as a wool balaclava. Wear wool whenever possible, since wool still provides considerable insulation even when wet. Avoid clothing which is tight fitting, especially at neck, wrists, and ankles, since it impedes the flow of blood, and hastens chilling of head, hands, and feet. In any case, tight fitting clothing prevents maintenance of the air space which is your most effective insulation.

Keep eating sweets and such foods all the time. This helps maintain the level of blood sugar, and thereby provides the body with readily used, immediately available fuel. Be careful that the sweets you get are not for dieters; such foods usually have no real sugar in them and are useless for fuel.

Avoid getting wet; it is better to take off your clothes and get your body wet, then put on your dry clothes again. That way you can get warm; if your clothes get wet, you may need to be rescued.

Avoid wind, and avoid sitting in drafts. If you wish to sit or lie down for a while, try to sit in a place where the wind is at a minimum. Provide yourself with a foam pad or a piece of spare clothing to sit on, thereby minimizing the conductive heat loss to the rock.

Above all, be aware of your own condition and symptoms, and keep alert to the condition of those around you. You may notice that they are in trouble before they do. Don't be ashamed to admit that you are not made of iron; if you are cold, the others probably are, too. Stop and get warm again if that is possible or otherwise head for the entrance.

Keep these dangers in mind, know what to do, and, if needed, do it without hesitation.

REFERENCES

Bangs, C. (1974)—"Sudden Survival," *Off Belay*, No. 18, December, pp 10-17.

Bowman, W., Jr. and Bunce, G. (1975)—"Injuries in the Winter Environment," *Emergency Product News*, No. 34, October, pp. 478-9, 540.

———— (1971)—*Emergency Care and Transportation of the Sick and Injured*, AAOS, Chicago.

Kreider, M.B. (1967)—"Physical and Physiological Factors in Fatal Exposures to Cold," *Natl. Speleol. Soc. Bull.* 29(1) 1-11.

Lathrop, T.G. (1972)—*Hypothermia*, The Mazamas, Portland, Oregon, rev. ed.

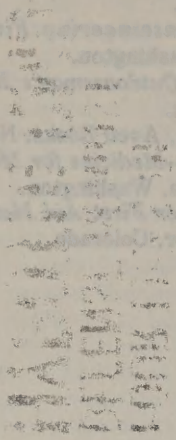
Mitchell, D. (1972)—*Mountaineering First Aid*, The Mountaineers, Seattle, Washington.

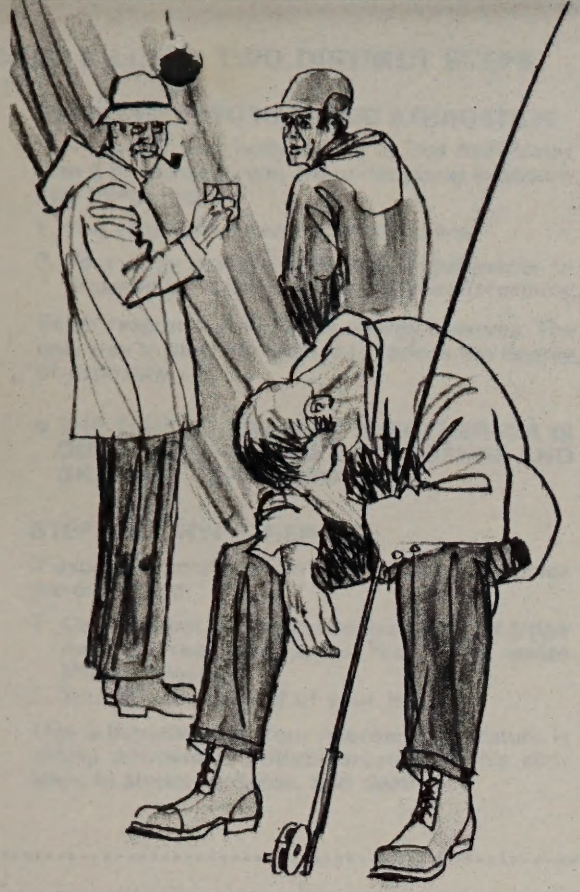
Nourse, A.E. (1974)—*The Outdoorsman's Medical Guide*, Harper & Row, New York.

Smith, A. (1968)—*The Body*, Avon Books, New York.

Wilkerson, J.A., ed. (1967)—*Medicine for Mountaineering*, The Mountaineers, Seattle, Washington.

————, (1973)—*Winter First Aid Manual*, National Ski Patrol System, Denver, Colorado.





THINK HYPOTHERMIA

If you are outdoors for recreation, you presumably do not intend to jeopardize your life.

Hypothermia may be a new word to you, but it's the *only* word that describes the rapid, progressive mental and physical collapse accompanying the chilling of the inner core of the human body.

Hypothermia is caused by exposure to cold, aggravated by wet, wind, and exhaustion. It is the #1 killer of outdoor recreationists.

- **TAKE HEED OF "HYPOTHERMIA WEATHER."**
- **WATCH CAREFULLY FOR WARNING SYMPTOMS.**
- **CHOOSE EQUIPMENT WITH HYPOTHERMIA IN MIND.**
- ***THINK HYPOTHERMIA.***

NOTES ON EQUIPMENT

Choose rainclothes that are proof against *wind-driven* rain and cover head, neck, body, and legs. Polyurethane coated nylon is best. The coatings won't last forever. Inspect carefully and test under a cold shower before you leave home. Ponchos are poor protection in wind.

Take woolen clothing for hypothermia weather: 2-piece woolen underwear...or...long wool pants and sweater or shirt. Include a knit cap that can protect neck and chin. Cotton underwear is worse than useless when wet.

A stormproof tent gives best shelter. Take plastic sheeting and nylon twine for rigging additional foul-weather shelter.

Carry trail food...nuts, jerky, and candy...and keep nibbling during hypothermia weather.

Take a gas stove or a plumber's candle, flammable paste, or other reliable firestarter.

- **DON'T WAIT FOR AN EMERGENCY. *USE* THESE ITEMS TO AVOID OR MINIMIZE EXPOSURE.**

The film
BY NATURE'S RULES
from which information for this brochure was taken, is made available, on loan, free to groups through:
ASSOCIATION STERLING FILM LIBRARIES
866 Third Ave.
New York, New York 10022

courtesy of SAFECO Insurance Companies, Seattle, Washington

® SAFECO Insurance Company of America, registered trademark owner.

AR-32 R1 2/73

PRINTED IN U.S.A.

FOUR LINES OF DEFENSE AGAINST HYPOTHERMIA

From the motion picture ...BY NATURE'S RULES

MOUNTAIN RESCUE

SAFECO INSURANCE

A public service of SAFECO Insurance Companies

COLD KILLS IN TWO DISTINCT STEPS

STEP ONE: EXPOSURE AND EXHAUSTION

The moment your body begins to *lose heat* faster than it produces it, you are under-going exposure. Two things happen:

1. You voluntarily *exercise to stay warm.*
2. Your body makes involuntary adjustments to preserve *normal temperature in the vital organs.*

Either response drains your energy reserves. The only way to stop the drain is to reduce the degree of exposure...

• THE TIME TO PREVENT HYPOTHERMIA IS DURING THE PERIOD OF EXPOSURE AND GRADUAL EXHAUSTION.

STEP TWO: HYPOTHERMIA

If exposure continues until your energy reserves are exhausted:

1. Cold reaches the brain depriving you of judgement and reasoning power. *You will not realize this is happening.*
2. You will lose control of your hands.

This is hypothermia. Your internal temperature is sliding downward. Without treatment, this slide leads to stupor, collapse, and death.

YOUR FIRST LINE OF DEFENSE: AVOID EXPOSURE

1. STAY DRY. When clothes get wet, they lose about 90% of their insulating value. Wool loses less; cotton, down, and synthetics lose more.
2. BEWARE THE WIND. A slight breeze carries heat away from bare skin much faster than still air. Wind drives cold air under and through clothing. *Wind refrigerates wet clothes* by evaporating moisture from the surface. WIND MULTIPLIES THE PROBLEMS OF STAYING DRY.
3. UNDERSTAND COLD. Most hypothermia cases develop in air temperatures between 30 and 50 degrees. Most outdoorsmen simply can't believe such temperatures can be dangerous. They fatally underestimate the danger of being wet at such temperatures.
   • 50 degree *water* is unbearably cold. The cold that kills is *cold water* running down neck and legs, *cold water* held against the body by sopping clothes, *cold water* flushing body heat from the surface of the clothes.

   • DON'T ASK, "HOW COLD IS THE AIR?" ASK INSTEAD, "HOW COLD IS THE WATER AGAINST MY BODY?"
4. USE YOUR CLOTHES. Put on raingear *before* you get wet. Put on wool clothes *before* you start shivering.

YOUR SECOND LINE OF DEFENSE: TERMINATE EXPOSURE

If you cannot stay dry and warm under existing weather conditions, using the clothes you have with you, *terminate exposure.*

1. BE BRAVE ENOUGH TO GIVE UP REACHING THE PEAK OR GETTING THE FISH OR WHATEVER YOU HAD IN MIND.
2. Get out of the *wind and rain.* Build a fire. Concentrate on making your camp or bivouac as secure and comfortable as possible.

NEVER IGNORE SHIVERING

Persistent or violent shivering is clear warning that you are on the verge of hypothermia. MAKE CAMP.

FORESTALL EXHAUSTION

Make camp while you still have a reserve of energy. Allow for the fact that exposure greatly reduces your normal endurance.

You may think you are doing fine when the fact that you are exercising is the only thing preventing your going into hypothermia. If exhaustion forces you to stop, however briefly:

1. Your rate of body heat reduction instantly drops by 50% or more.
2. Violent, incapacitating shivering may begin immediately.
3. You may slip into hypothermia in a matter of minutes.

APPOINT A FOUL-WEATHER LEADER

Make the best-protected member of your party responsible for calling a halt before the least-protected member becomes exhausted or goes into violent shivering.

YOUR THIRD LINE OF DEFENSE: DETECT HYPOTHERMIA

If your party is exposed to wind, cold, and wet, THINK HYPOTHERMIA. Watch yourself and others for symptoms.

1. Uncontrollable fits of shivering.
2. Vague, slow, slurred speech.
3. Memory lapses. Incoherence.
4. Immobile, fumbling hands.
5. Frequent stumbling. Lurching gait.
6. Drowsiness (to sleep is to die.)
7. Apparent exhaustion. Inability to get up after a rest.

YOUR FOURTH AND LAST LINE OF DEFENSE: TREATMENT

The victim may deny he's in trouble. Believe the symptoms, not the patient. Even mild symptoms demand immediate, drastic treatment.

1. Get the victim out of the wind and rain.
2. Strip off *all* wet clothes.
3. If the patient is only mildly impaired:
   a. Give him warm drinks.
   b. Get him into dry clothes and a warm sleeping bag. Well-wrapped, warm (not hot) rocks or canteens will hasten recovery.
4. If the patient is semi-conscious or worse:
   a. Try to keep him awake. Give warm drinks.
   b. Leave him stripped. Put him in a sleeping bag with another person (also stripped). If you have a double bag, put the victim between *two* warmth donors. *Skin to skin contact* is the most effective treatment.
5. Build a fire to warm the camp.

BLM LIBRARY
SC-653, BLDG. 50
DENVER FEDERAL CENTER
P. O. BOX 25047
DENVER, CO 80225-0047

BLM LIBRARY
RS 150A BLDG. 50
DENVER FEDERAL CENTER
P.O. BOX 25047
DENVER, CO 80225